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Lower Butte Creek Project

Characterization and Analysis of Small Pumping Plant Sites on the Sutter Bypass East Borrow Channel

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TABLE OF CONTENTS

List of Figures

List of Tables

Appendices

1.0 Introduction

The Sutter Bypass, located in Sutter County, California, originates at the south side of the Sutter Buttes and terminates at the intersection of the Sacramento River and the north end of the Yolo Bypass (Figure 1). The bypass was constructed during the 1920s to contain floodwaters and protect adjacent farmlands. The land contained within the bypass is both privately and publicly held and utilized for wildlife habitat and agricultural purposes. Most properties hold water rights that allow them to pump out of the Bypass' West Borrow and East Borrow Channels. This report characterizes the pumping plant sites and equipment necessary to screen several small diversions that pump out of the East Borrow Channel.

Figure 1: Vicinity Map

1.1 Background

This evaluation is a component of the stakeholder driven Lower Butte Creek Project (LBCP). The LBCP was initiated in 1997 to improve fish passage in accordance with the Anadromous Fish Restoration Program (APRP). It specifically focuses on developing a set of operational alternatives for the Lower Butte Creek Region that improves fish passage yet maintains the viability of agriculture, government lands, and wildlife habitats.

There have been two phases of the LBCP. The initial phase brought stakeholders together to address the diverse issues associated with using water from the Lower Butte Creek system. These meetings culminated in the development of six alternatives to improve fish passage and address the key issues. At the conclusion of this phase, it was agreed that additional data was needed to effectively implement the alternatives. Hence, Phase I-B was developed to collect and analyze data to facilitate future stakeholder decisions. This data included analysis of key water control structures in the West Borrow Channel, evaluation of alternative water sources, and the current water use in the East Side Sutter Bypass.

During both of these phases significant discussions were held on the improvement of fish passage, specifically within the East Borrow Channel, and whether water users should be required to screen their diversions. There is speculation on whether screening would actually minimize the take of fish species and effectively contribute to fish recovery. These discussions have led to a three-phased Restoration Approach involving the signing of a Memorandum of Agreement, development of a Cooperative Restoration Plan for the East Borrow Channel, and the implementation of this Plan.

This report, as part of this restoration approach, specifically focuses on data collected on the smaller scale diversion pumps within the East Borrow Channel. This information will be of assistance when accessing the fish screen alternatives during the development phase of the East Borrow Channel Restoration Plan.

1.2 Project Site

The East Borrow Channel is a key component of the Butte Creek system. The channel extends 30 miles along the east side of the Sutter Bypass from the East-West Diversion Weir on the downstream end of the Butte Slough to the Nelson Slough (Figure 1). The Sutter Bypass consists of approximately 11,000 acres of agricultural lands (primarily rice fields) and 2,500 acres of wetland habitat. Water entering the bypass primarily consists of natural flow from Butte Creek and the Butte Sink. In the spring, the Bypass serves as a flood plain, alleviating flooding potential along the lower Sacramento River. When the Bypass is not flooded, flow is restricted to the East and West Borrow Channels. Three waterways, the Willow, Gilsizer, and Nelson Sloughs, convey water from the East Borrow Channel in a southwesterly direction across the Sutter Bypass to the West Borrow Channel. Gilheizer Slough was blocked off during the 1950s.

The Butte Slough Irrigation Company regulates the flow of water into both the East and West Borrow Channels via the East-West Diversion Weir. In the East Borrow Channel, water is diverted from 46 individual diversions for the irrigation of fields within and outside of the Sutter Bypass. These diversions consist of pumps ranging from 8” to 22” in diameter. Typically these diversions occur during the irrigation season from April to October and at a smaller scale during the fall and winter for rice straw decomposition and wetland habitat. In addition to these diversions, three DWR pumping stations pump water out of the channel for irrigation and conversely pump water into the channel for flood protection. At the channel terminus water is conveyed through Nelson Slough into the West Borrow Channel, then into Sacramento Slough where it enters the Sacramento River at Verona.

2.0 Purpose and Methodology

This document will serve as a resource during the development of the Restoration Plan for the East Borrow Channel. The objective of this report is to characterize the site conditions and provide recommendations on the type, size, and configuration of fish screens that would be most conducive for selected diversion sites on the East Borrow Channel. Specific tasks include the following:

- *3.0 Data Collection*: This includes a topographic survey of the sites, water rights information, and pump information and other data as necessary to evaluate screening options.
- *4.0 Fish Screen Assessment:* Evaluation of fish screen design criteria and feasible fish screen options.
- *5.0 Analysis and Results:* Development of fish screen alternatives based on pumping capacity and site specific constraints at each of the diversion sites. Alternatives are presented for the screening of each diversion sites independently and for screening sites where diversions could potentially be consolidated.
- *6.0 Conclusion and Recommendations:* Recommendations are provided considering costs and performance capability.

3.0 Data Collection

Information collected by MBK Engineers (MBK) during Phase I-B of the Lower Butte Creek Project show that there are 46 individual diversions in the East Borrow Channel that are primarily used to irrigate adjacent fields. Twenty-four of these sites and two sites that pump from the West Borrow Canal were selected for this study with the cooperation from the pump owners. The remaining 22 pump sites are located outside of the Sutter Bypass east levee and are the subject of a California Department of Water Resources study. The collection of water rights information, surveys of the location and key features of each of the sites, and a follow up mailing was conducted. These tasks are described in further detail below:

Water Rights

MBK gathered information on the water rights at the diversion locations from the State Water Control Board. Landowners for each of these water rights were invited to a stakeholder meeting where they had the opportunity to meet with MBK to review and verify their water rights, and contribute additional information. The diversion sites of the active participants were selected for this study.

Surveys

Whitehead & Associates surveyed the selected diversion sites in the summer of 2002, collecting information on the local topography and key features of the pumps. Over the course of two years, several pumps were added and ownerships changed. Ducks Unlimited, Inc conducted a follow up survey in the fall of 2004 to fill in missing data gaps. The horizontal and vertical datum used for this project is California Zone 2, NAD 1983 and NAVD 1988, respectively.

Mailing

In the fall of 2004, Ducks Unlimited sent a package to all participating landowners containing a chart of the collected pump information for their specific diversion site(s) and a map showing the location of their site(s). The landowners were asked to verify the information and fill in any missing pump data on the chart.

Appendix A summarizes the information collected for each of the selected sites and Appendix B contains the collected topographic survey data.

4.0 Fish Screen Assessment

Fish screens are intended to protect the fisheries resource by safely excluding fish from diverted water. In order for these systems to achieve their purpose they must be reliable, effective and efficient. In other words, they must be designed in a manner that allows water diversion with minimal maintenance. Screens that routinely clog with debris could result in reduced diverted flow, damaged infrastructure, and localized increased velocities or "hotspots" that impinge fish. Fish screens can easily become the most expensive and burdensome component of small diversions. If not designed properly such screens could be perceived as merely a nuisance by frustrated operators and bypassed or discarded. Therefore, a robust design will be one that not only meets the screening criteria but also keeps the end user in mind.

Fish screens range from complex systems designed specifically for a particular situation to small, off the shelf, low-tech systems. As individual units the small pump diversions being considered in this analysis don't warrant the expense of complex systems, which are normally used for large diversions. However, if several of these were consolidated into a single diversion, a more extensive system may be practical. This section describes the general features of these screens and the design criteria fish screens must comply with in California.

4.1 Fish Screen Features

There are several options inherent to the selection of fish screens. These include the structure and shape of the screen, type of screen material, and the method of cleaning. Screens may also be customized to adequately address specific site constraints. These options are discussed below.

Structure/Shape

Fish screens range in size and structure from a simple screen attached to the suction side of a pipe to large expansive structures that span the width of large channels. The diversions along the East Borrow Channel are of a relatively small scale, which would lend them towards the former category. If several of the sites were consolidated, however, a larger, more complex fish screen may be necessary

Screen shape refers to the geometry of the screening surface and affects how water flows past and through the screen. Common shapes include flat plate, drum or cylindrical and cone. Flat plate screens are most common in larger more complex installations although they have been utilized in small box structures built around the intake. These screens are normally used in instances such as on a riverbank where the majority of the water flows past the screen, sweeping fish and debris with it. Normally they are not suited nor allowed for installations on dead-end sloughs or turnouts. Cylindrical screens are common on small diversions and often are designed with an integrated flange that attaches directly to the intake pipe. Drum and cone screens most often require the use of some form of adaptive piping to connect them to the diversion works and can designed for all sizes of diversions. Of the common screen types available, cylindrical and cone screens are best suited for dead-end sloughs, turnouts or locations with low or zero velocities This is because they don't rely on a bypass or sweeping flow to prevent fish impingement (This criteria is a function of the length of screen a fish is exposed to while traveling with the current. Cylindrical and conical shapes usually expose the fish to a much shorter length of screen).

Screen structure refers to how these screens are connected. For instance, the screen can be a single installation, bolted directly to the intake pipe, or multiple installations connected together with the use of a manifold. This allows the designer to better accommodate site conditions. For instance, if a given screen area is required to pass a desired flow but the size of the screen providing the area is too large for the site conditions, multiple smaller screens could be installed at the location that sum up to the required area. In this manner manifolds can be used to increase the capacity of a given screen size and shape.

Screen Material
Screens are manufactured with a variety of materials, stainless steel being the most common. The chosen material is configured into the screen using various methods. These include wedge wire bar, profile bar, perforated plate, and woven screens. Wedge wire and profile bar provide good structural support consisting of parallel stainless steel bars that may be oriented vertically or horizontally on flat plates or rolled into any of the conical shapes. The woven wire mesh screen is made of a woven wire in a criss-cross pattern. The perforated plate is a sheet metal with an array of holes and is available in a variety of configurations. All of these screens are available in a wide range of opening sizes and wire gages. The design criteria specify the maximum opening size for each of these screen types.

Self-Cleaning and Passive Systems
There are a variety of systems that may be installed on a fish screen to clean it. Many of these systems can be controlled remotely or on an automatic mode. Air-burst backwash cleaning systems clean through the induced violence from the air bubbles that free debris from the screen. Like air-burst systems, water-jet cleaning systems clean the screens from inside out. A jet of water sprays through the screen dislodging any debris that might be impinged on its surface. Mechanical brush systems and rotating drums have also been used effectively. A variety of power systems have been used to provide power to the cleaning systems. These include electric motors, diesels motors, hydraulic motors, paddle wheels and solar power. The key to self-cleaning screens is that they automatically clean the screen at set intervals that prevent clogging and, as a result, hot spots, head loss and decreased diverted flows. Some more complex screens utilize sensors that monitor the head loss through the screen since this is a direct correlation to cleaning performance.

The most low-tech cleaning method is a passive system. Passive systems do not have a self-cleaning mechanism. This is a screen installation where the operator is required to routinely clean the screen of any debris or algae buildup. Due to the uncertainty of this maintenance regulatory agencies require these screens to be oversized to account for clogging. Obviously this system can place a large time burden on an operator and in certain circumstances prove ineffective. Passive cleaning systems range from a hand-held brush to manually operated valves for water spray or air burst systems. Passive screens are generally cheaper than their counterparts and cannot mechanically fail from auxiliary cleaning equipment. These screens are most effective in waters that do not have a lot of debris and sediment.

4.2 Design Criteria for Fish Screens

The National Marine Fisheries Service (NMFS) and the California Department of Fish and Game (DFG) have developed a set of criteria for the design and maintenance of fish screens. These standards provide assurance that the installed screens will meet an expected standard of performance. The criteria that govern a design vary between sites, depending upon the type of channel or water body, the magnitude of diversion, and the species of fish present in the system. For this study we are considering small pumped diversions. The DFG Screening Criteria (Appendix C) states that "Small pumped diversions (less than 40 cubic-feet per second) which are screened using "manufactured, self-contained" screens shall conform to the National Marine Fisheries Service - Southwest Region criteria." The National Marine Fisheries Service- Southwest Region criteria is provided in Appendix D and their criteria for small pumped diversions are summarized below:

Approach velocity, self-cleaning

The approach velocity is the velocity component perpendicular to the fish screen and should be measured approximately 3 inches from the screen surface. For fish screens with a self-cleaning device, the required maximum approach velocity is 0.40 ft/sec and should be uniform across the fish screen.

Approach velocity, not self-cleaning

For fish screens that do not have a self-cleaning device, the required maximum approach velocity is 0.1 ft/sec and should be uniform across the screen.

Sweeping velocity

The sweeping velocity is the velocity component parallel to the fish screen. The sweeping velocity should be higher than the approach velocity with recommended velocities of 2 ft/sec or greater.

Total submerged area

The total submerged area shall equal the maximum diverted flow divided by the allowable approach velocity. For drum screens, the design submergence shall be 75% of the drum diameter where submergence should not exceed 85% or be less than 65% of the drum diameter.

Equation 1: $$Submerged\ A = \frac{Q_{\max}}{V_{all}}$$

Where:

Submerged A = submerged area

$Q_{\max}$ = maximum diverted flow

V_{all} = allowable approach velocity

Screen orientation
Screens that are six feet or less in length may be angled perpendicular to the flow. For screens longer than 6 feet, the screen to flow angle must be less than 45 degrees.

Screen face material
Perforated plate material (round opening) shall not exceed 3/32 inches diameter, profile bar (slotted opening) shall not exceed 0.0689 inches, and woven wire (rectangular opening, measure diagonally) shall not exceed 3/32 inches. There shall be a minimum of a 27% open area. Stainless steel and other corrosion resistant material is recommended to minimize clogging and corrosion. Anti-fouling material should also be considered if biological fouling problems are a potential problem. Care should be taken to not use any materials that may be harmful to fish or other wildlife.

Maintenance
Screens shall be automatically cleaned as often as necessary to prevent the accumulation of debris. It is recommended that proven cleaning technologies are used and that the system is effective and reliable. For intermittent type systems, the head differential shall be a maximum of 0.1 feet, unless otherwise agreed to by NMFS.

5.0 Analysis and Assumptions
This section discusses site selection factors and provides a series of fish screen alternatives and the estimated costs for each alternative. Alternatives are presented for the screening of each diversion site (Alternative A) and for sites where diversions within close proximity to each other are consolidated into larger diversions (Alternative B).

5.1 Site Specific Factors
In addition to the design criteria, there were a variety of site specific factors that were considered in developing the feasible screening alternatives and recommendations. These factors are discussed below.

Species of fish
Fish screens must meet certain design criteria depending upon the fish species that they are intended to protect. The fish species that are of concern and govern the screening criteria in this report are the salmonids. Fall, late fall, winter and spring run salmon as well as steelhead and the Sacramento Split Tail are present in the Sutter Bypass. It is stated in the California Fish Screen Criteria that, unless proven otherwise, it should be assumed that juvenile fry salmonids are present in the waters. Fry are present in East Borrow Channel, mandating a maximum approach velocity of 0.4 ft/sec.

Magnitude of diversion
The pumping capacity directly correlates to the minimum screen surface area needed to achieve an adequate approach velocity. As described in the design criteria, the total submerged area equals the maximum diverted flow divided by the allowable approach velocity. Depending upon the size, fish screens may be designed to traverse a portion of a channel or to simply surround the pump bowl.

Channel geometry
The channel geometry affects several factors in the design including, but not limited to, how the water flows past the proposed screen, the type and dimensions of screen that can be installed, and the depth of water available for screening, amount, if any, of bypass flow, etc. Often fish screens require a minimum depth of submergence. Clearly the channel geometry has a major impact on the size and type of screens that can be installed at a particular site. In some instances it is better to move the diversion to a more suitable location.

Channel bottom
In channels where there is a large amount of silt and other deposition, fish screens may need to be placed at a higher level to reduce the potential for clogging. Scour as well as channel meandering must also be considered.

Corrosion
Screens must be protected against corrosion for both longevity and function. Stainless steel is commonly used but other anti-fouling systems such as cathodic protection are often implemented. The water in the East Borrow Channel consists of runoff from the Butte Creek and the Butte Sink. Although it is fresh water, it contains a high amount of agricultural discharge and as such has a high potential for electrolysis. At a minimum stainless steel materials should be utilized.

Potential for biofouling
Algae and other organisms grow on fish screens and could adversely affect performance. It is important to provide a mechanism for keeping the screens clean.

Construction Window
The timing of when diversions most frequently occur as well as when sensitive fish species are present is important in scheduling the installation and maintenance of the fish screens. In the East Borrow Channel, water use peaks during the irrigation season from April to August. The highest demand is in June. Diversions gradually taper off in September and October. The installation of the fish screens should occur during this time period.

Access
Access to the sites may influence construction costs. Sites located on the outside of the Sutter Bypass (east side) are generally more accessible than the sites on the Bypass interior (west side). Accessibility should be considered when estimating costs during the final design phase.

Maintenance
The amount of maintenance required will depend upon to type of system installed and particular site conditions. Maintenance will be most intense during the irrigation season. Fish screens in channels carrying larger sediment loads will require frequent cleaning and maintenance. Utilizing screens with self-cleaning mechanisms can minimize maintenance activities.

5.2 Assumptions

Assumptions made in order to facilitate the screen evaluations are presented below:

Design Diversion Flow

Water Rights information was collected by MBK in order to determine the legal diversion amounts of the pump sites considered in the study. This information can be misleading since the actual diverted flow does not necessarily have to comply with the stated Water Rights flow. Therefore, in order to properly categorize the pumps the maximum pumping capacity had to be determined. In every case the pump curve data had long since been lost and as such owner-stated capacities were used in this study. Not all owners were aware of the pumping capacity however, and in some instances the capacities were estimated in order to complete the data set. Several approaches were taken in an attempt to verify the estimates, which proved to have a high level of uncertainty. Therefore, unless the estimated pump flows were a part of a combined analysis the pumps were not carried forward in the analysis. This was deemed appropriate at this level of study since the pump sites are similar and costs to screen uncertain sites can be predicted based off of the other known ones. Figure 2 shows the pumping capacity distribution as reported by the landowners.

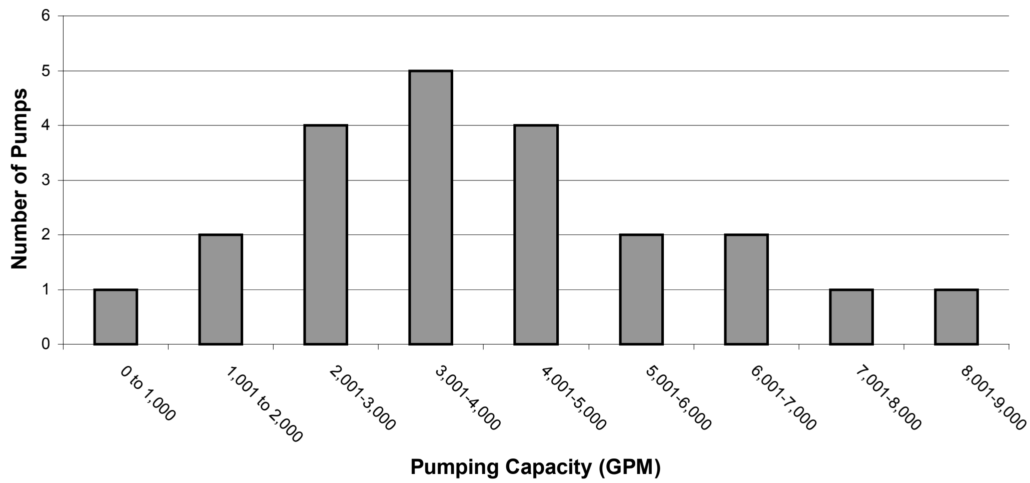


Figure 3
Pump Capacity Distribution

Design Water Surface Elevation

Weir 2 and the Willow Slough Weir control the water levels within the East Borrow Channel. For design purposes it was assumed that the worst-case scenario (i.e. lowest water level) would be when these weirs were at their operating level and no new flow was entering the bypass. This would result in a water surface elevation at a particular diversion site equal to the sill elevation of the closest downstream weir. According to the California Department of Water Resources, the operating elevation at Weir 2 is 37.7-feet and the Willow Slough Weir 27.9-feet, NAVD 1988. These elevations were used in conjunction with the site topography in determining design water depths at the respective diversion sites.

5.3 Analysis

Data collected under this study were used to evaluate the feasibility of screening the small East Borrow Channel pumps. This process is detailed below:

Site Evaluation

Diversion conditions at the pump sites typically consist of shallow water of minimal velocity. While the majority of the pumps are located on the banks of the East Borrow Channel, some are located in side channels or small basins. The channel banks are mostly overgrown and the bottom consists of soft mud. Water within the East Borrow Channel consists of agricultural runoff and carries a high silt load. The bypass receives floodwaters in winter months and is submerged for long periods at a time. Pump motors are pulled prior to this annual occurrence. Survey data is presented in the Appendix B.

Pump Evaluation

All of the pumps considered in this report are turbine pumps, which are a variety of suction pump characterized by a motor mounted above the water surface that is attached to a submerged centrifugal pump by a long shaft. The centrifugal pump contains an impeller that, when spun, pushes water up the intake pipe where it exits out the discharge just below the motor. Several types of impellers and pump bowls exist, and since the intakes were all submerged during the data collection phase this information was not collected. It is assumed that in order to facilitate installation of the fish screens the preferred design would have to be readily adaptable to any pump bowl configuration.

Screen Selection

The diversion sites on the East Borrow Channel are relatively small. As such a number of screening options exist where screens that surround the pump bowl can be utilized. This is fortunate, as it will result in less-costly screens. In addition, large diversions, which need a correspondingly larger screen area, commonly deploy flat plate screens that span part of the waterway. Since the bypass floods on a yearly basis these screens could potentially trap fish behind them as waters recede or be damaged by high flows and debris.

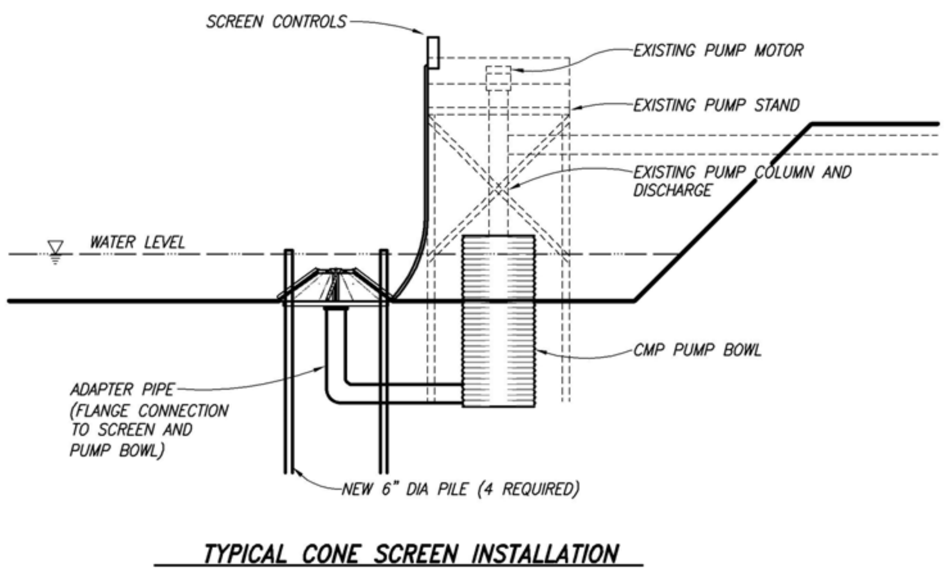
Since the preferred screen design must be applicable to a variety of pump bowl shapes and orientations, it was decided that the screens would be designed to attach to a flange on a vault. The vault in turn would be designed in a fashion that surrounds the pump bowl sealing off all water entry except for through the screen. This vault would be fitted with a flange attachment for connection with the fish screen and could take the form of a fabricated metal box or section of a large diameter CSP pipe. The basic vault design could be consistent for all pump sites but would have to be modified slightly to accommodate the vertical verses slant pumps. The vaults could be fitted with a cover that would prevent fish entrainment during high water events.

Evaluation of the site conditions concluded that cylindrical or cone screens would be most appropriate for the diversions. Of the possible screen configurations, these exhibit the best properties for use in shallow water conditions and function in high silt conditions. Cone screens have a robust reputation for these types of conditions and the cylindrical screens have proved effective on smaller installations.

Cone screens have several inherent features that make them particularly appropriate for shallow water/ high silt conditions. The conical shape of the screen means that they provide a large surface area with a comparatively short height, with the majority of the surface area located on the lower portion of the screen. This provides insurance against water level fluctuations that might drop into the zone of the screen. The approach velocity of the cone screen design, with a greater percentage of its surface area biased towards the bottom of the screen, isn't affected as dramatically as a screen with a surface area that's evenly distributed. Secondly, cone screens pull water from the top down, which means they don't have the tendency to suck sediment off the channel bottom, as some other designs do, and in fact can be nestled down into the mud to maximize use of the water column. The screens are cleaned by a mechanical brush system, which is operated by a hydraulic pump located inside the screen and powered by the existing electrical supply or by solar power. The cleaning frequency is automated and can be adjusted to accommodate for changing site conditions. These screens can be retrofitted onto an existing pumping facility by installing an adapter pipe that surrounds the pump intake and creates a base to set the screen on. The screens rest on piles driven around the intake and are held in place by gravity. They can be easily removed using the same equipment the operator uses to pull pump motors. Maintenance is minimal and should consist of checking hydraulic fluid levels, hoses for cracks and any anodes used for cathodic protection. Most of this could be done at the end of the pumping season when the screen is removed for winter. The main disadvantage of cone screens is that the cost of installation is substantially higher than cylindrical screens. However, this is somewhat offset by the greater capacity and compactness of the screens. The screens are currently manufactured in three sizes, 8-foot, 10-foot and 12-foot diameter bases, with corresponding capacities of 9,800 gpm, 16,000 gpm and 23,700 gpm respectively.

The primary advantages of cylindrical screens are their low cost and ease of installation. The screens are manufactured with an integral flange that can be bolted to the pump intake pipe if a flange is present, although in many cases a flange would need to be added to the existing intake. The screens come in a variety of sizes and multiple screens can be installed on a single intake with the use of a manifold. The screens can be installed in any orientation. For soft bottom/shallow water conditions the screens can be installed vertically resting on a flat plate or concrete pad to eliminate the suction of bottom silt. As with the cone screen, the cleaning system contains moving parts. Unlike the cone screen, however, all moving parts are located inside the screen. A rotating bar inside the screen contains nozzles that spray water jets through the screen surface, dislodging debris. This system operates continuously and is driven by a flow of water returning to the screen through a return line from the pump discharge. This means that efficiency of the pump is reduced somewhat by water lost through the cleaning system. Smaller installations (100 gallons per minute) can see a reduction in diverted flow of around 10% while larger diversion (8,500 gallons per minute) might experience a reduction in flow at a more modest 2%. The efficiency would be reduced even further if a multiple-screen installation were used. The primary maintenance requirement is the periodic cleaning of the back-spray filter, which filters water returning from the pump discharge to the spray nozzles. Depending upon the water quality this filter could require cleaning anywhere from once every few weeks to multiple times a day. If the filter fails or is over-loaded spray nozzles may become clogged and require cleaning. All seals are comprised of pump shaft seals and as such are relatively maintenance free. Any anodes installed on the screen would require periodic replacement. Numerous screen sizes are available and special dimensions can be made to order on an as needed basis.

In conclusion, both screens would function in the East Borrow Channel. Although the cone screen are better suited to shallow water applications, the cylindrical screens were deemed the most appropriate for the smaller diversions, based solely upon their lower installation cost. Cone screens would be considered in instances where the site conditions or diversion quantities made them more cost efficient or reliable. Figure 3 provides a schematic of typical cone and cylinder installations as proposed under this study.



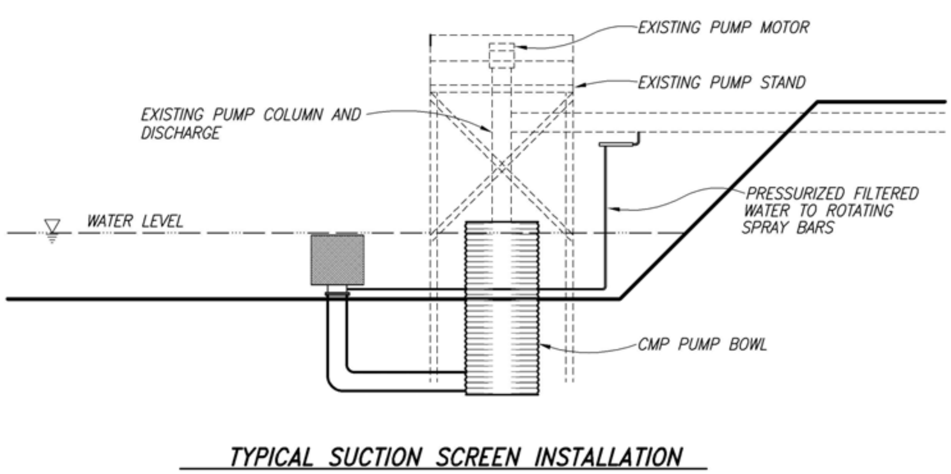


Figure 3: Typical Cone and Suction Screen Installation

5.4 Results
Three alternatives were considered in screening the pumps, 1) screening each individual pump 2) screening each pump site independently and 3) consolidating pump sites where feasible. These alternatives are presented below:

5.4.1 Alternative A - Screen Individual Pumps
The screen options presented under Alternative A assume that each pump is individually screened. Although the pumping capacities along the East Borrow Channel are relatively small, the capacities and site conditions still vary enough to require each site to be assessed independently. The small diversion rates result in cylindrical screens being the preferred method. The variety of cylindrical screen sizes means that they can be readily tailored for each pump installation. Pump basins might require cleaning in some instanced to allow for screen installation. This would require the mobilization of equipment and add to the installation costs. In all cases additional fittings will need to be added onto the existing pump intake and discharge lines. Some pumps may require a new intake line altogether. Since the cleaning mechanism is operated by hydraulic pressure no electrical work would be required. The operator may need to perform some clearing work around the screen prior to resuming seasonal pumping operations. Table 1 shows screen selection for the individual pumps

5.4.2 Alternative B – Screen Individual Diversion Sites
The screen options presented under Alternative B assume that each pump site would be individually screened. This means that only pump sites with two or more pumps would be consolidated together; All other pumps would be screened individually as stated under Alternative A. The sites consolidated under Alternative B are Sites 15A, 19, 21, 22, 23 and 24.

Table 2 shows the Screen Selection for the combined sites. The intention of this alternative is to fashion a vault around both pumps at a site with a common screened inlet. For pumps separated by a distance that makes this impractical separate vaults connected by a common manifold could be constructed.

5.4.3 Alternative C – Screen Consolidated Diversion Sites
Instead of screening each site, there is also the possibility of consolidating certain pumping sites into one single diversion. This would further reduce the number of diversions along the East Borrow Channel and eliminate the need to screen each individual diversion. This alternative would require the relocation of pumps and construction of delivery ditches and/or delivery pipelines to move the water to its final destination. Sites that could potentially be consolidated are listed in Table 3. All other sites would be screened according to Alternative A.

Table 1: Screen Selections for Alternative A

Site	Number of Pumps	Site Capacity (gpm)	Design Water Depth	Type	Number of Screens	Capacity (gpm)	Height (inches)	Diameter (feet)
	Site Characteristics			**Screen Characteristics**				
1	1	2,000	2.7	Drum	1	2,000	2.8	2.0
2	1	4,000	3.6	Drum	1	4,000	3.8	3.0
5	1	4,471	5.8	Drum	1	4,500	4.5	3.0
7	1	1,350	2.7	Drum	1	1,400	2.1	2.0
7A	1	NA	NA	Drum	1	NA	NA	NA
8	1	890	2.1	Drum	1	1,000	1.7	2.0
12	1	3,500	5.6	Drum	1	3,600	3.4	3.0
13	1	4,000	3.2	Drum	2	2,000	2.8	2.0
14	1	3,000	3.3	Drum	1	3,000	3.3	2.5
15A	2	NA	5.1	Drum	1	NA	NA	NA
15B	1	NA	4.9	Drum	1	NA	NA	NA
15C	1	2,200	6.3	Drum	1	2,400	3.3	2.0
16	1	NA	4.4	Drum	1	NA	NA	NA
17A	1	7,000	6.7	Drum	1	7,000	6.6	3.0
17B	1	2,800	4.8	Drum	1	3,000	3.3	2.5
17	1	7,000	5.2	Drum	2	7,200	3.4	3.0
18	1	NA	7.1	Drum	1	NA	NA	NA
19	2	NA	7.9	Drum	1	NA	NA	NA
20	1	7,275	5.3	Drum	2	7,200	3.4	3.0
21	2	5,000	5.5	Drum	1	5,000	4.9	3.0
		6,000	5.5	Drum	1	6,000	5.8	3.0
22	2	5,000	6.0	Drum	1	5,000	4.9	3.0
		6,000	6.0	Drum	1	6,000	5.8	3.0
23	2	3,800	5.9	Drum	1	4,000	3.8	3.0
		4,000	5.9	Drum	1	4,000	3.8	3.0
24	2	8,556	5.3	Drum	2	9,000	4.5	3.0
		4,311	NA	Drum	1	4,500	4.5	3.0
25	1	2,200	23.0	Drum	1	2,400	3.3	2.0
1W	1	1,500	NA	Drum	1	1,600	2.3	2.0
2W	1	300	NA	Drum	1	300	1.4	1.2

Table 2: Consolidated Screen Selections for Alternative B

	Site Characteristics			Screen Characteristics				
Site	Number of Pumps	Site Capacity (gpm)	Design Water Depth	Type	Number of Screens	Capacity (gpm)	Height (inches)	Diameter (feet)
15A	2	NA	5.1					
19	2	NA	7.9					
21	2	11,000	5.5	Cone	1	16,100	37	10.0
22	2	11,000	6.0	Cone	1	16,100	37	10.0
23	2	7,800	5.9	Cone	1	9,800	29	8.0
24	2	12,867	5.3	Cone	1	16,100	37	10.0

(NA= Not Available)

Table 3: Consolidated Screen Selections for Alternative C

	Site Characteristics			Screen Characteristics				
Consolidated Sites	Number of Pumps	Site Capacity (gpm)	Design Water Depth	Type	Number of Screens	Capacity (gpm)	Height (inches)	Diameter (feet)
15A & 15B	3	NA	5.1					
19 & 21	4	NA	5.5					
20 & 22	3	18,275	5.3	Cone	1	23,700	45	12
23 & 24	4	20,667	5.3	Cone	1	23,700	45	12

(NA= Not Available)

5.4.4 Probable Costs

The costs of the alternatives described above are presented in Table 4. The costs presented represent an estimate of material and labor costs for installing the screens as indicated in the results. These costs are intended to provide an order of magnitude level only. Each site contains specific conditions and constraints that would affect the actual installation costs. Furthermore, implementation of Alternative C would necessitate the construction of additional infrastructure including, but not limited to, delivery ditches, pipelines and possibly new pumping stations. These appurtenances were beyond the scope of this study and are not included in the costs in Table 4.

Table 4: Probable Costs for Implementing Alternatives A, B and C

Item	Alternative A	Alternative B	Alternative C
Field Pump Tests	$20,000	$20,000	$20,000
Project Design	$50,000	$50,000	$80,000
Project Permitting	$50,000	$50,000	$50,000
Construction Management	$50,000	$50,000	$50,000
Construction	$700,000	$990,000	$800,000
Total	$870,000	$1,160,000	$1,000,000

6.0 Conclusion and Recommendations

Screening the small pumps on the East Borrow Channel is feasible and would be most economically accomplished utilizing small cylindrical screens on each individual pump. Consolidation of sites would reduce the number of diversions and result in fewer facilities requiring maintenance but would come at a substantial capital investment.

The results presented in this report are based on the assumptions described herein and are sufficient for this level of study. Prior to implementation of the screening effort field tests should be performed on each pump to be screened in order to verify the maximum pumping capacity and select the appropriate screen size.

7.0 References

California Department of Fish and Game. June 2000. Fish Screening Criteria. http://www.dfg.ca.gov/nafwb/fishscreencriteria.html

Department of Fisheries and Oceans, Canada. March 1995. Freshwater Intake End-of-Pipe Fish Screen Guideline.

National Marin Fisheries Service Southwest Region. January 1997. Fish Screening Criteria for Anadromous Salmonids. http://www.krisweb.com/biblio/gen_noaa_nmfs_1997_fishscreens.pdf

Nordlund, Bryan. National Marine Fisheries. June 1996. Designing Fish Screens For Fish Protection at Water Diversions. http://www.nwr.noaa.gov/1hydrop/hydroweb/docs/usfws_97.htm

Screen Services. 1999. Static Orb Screens.

APPENDICIES

Appendix A
Data Collected for the Pump Sites

Appendix A – Information Collected for each Diversion Site

Site	Owner	Pump Information Contact	Water Rights		Pump Characteristics						
			Type Water Right	Maximum Diversion Right, cfs	Number of Pumps at Site	Power, HP	Lift, feet	Approximate Pumping Capacity, GPM (cfs)	Intake Discharge Size, inches	Placement Relative to Edge of Channel, feet	Pumps in or out of Sutter Bypass
1	Douglas (Kermit) Tarke	Craig Tarke	Movable	2.66	1	15	9	2,000 (4.5)	12	Recessed	In
2	Ross Madden	Ross Madden	Stationary	7.25	1	30	10	4,000 (8.9)	16	Edge of Canal	Out
5	David Nall	David Nall	Stationary	3	1	30	Contact did not know	4,471 (10)	18	Few Feet	Out
7	Lorreta Dean	Lorreta Dean	Stationary	1.13	1	7.5	4	1350 (3.0)	10	Recessed, in Interior Slough	In
7A	Jeager Construction Bill Jaeger	Bill Jaeger	Stationary	1.65	1	20	5	Contact did not know	10	100	In
8	Pat Laughlin	Pat Laughlin	Stationary	0.65	1	5	4	890 (2.0)	8	Edge of Canal	In
12	David Creps	David Creps	Stationary	10	1	15	Contact did not know	3,500 (7.8)	16	In Channel Crossing Sutter Bypass	In
13	David Creps	David Creps	Stationary	4.7	1	15	Contact did not know	4,000 (8.9)	16	Recessed by 200 feet	In
14	David Creps	David Creps	Stationary	4.7	1	10	Contact did not know	3,000 (6.7)	16	Few Feet	In
15A	Fred Zielesch	Fred Zielesch	Movable	17.82	2	20	Contact did not know	Contact did not know	18, did not know other	did not know	In
15B	Fred Zielesch	Fred Zielesch	Movable	17.82	1	15	did not know	Contact did not know	18	Edge	in
15C	Richard Giusti	Lance Mateoli	Movable	17.82	1	10	4	2,200 (4.9)	18	Edge	Out

Appendix A, Continued

Site	Owner	Pump Information Contact	Water Rights: Type Water Right	Water Rights: Maximum Diversion Right, cfs	Pump Characteristics: Number of Pumps at Site	Power, HP	Lift, feet	Approximate Pumping Capacity, GPM (cfs)	Intake Discharge Size, inches	Placement Relative to Edge of Channel, feet	Pumps in or out of Sutter Bypass
16	Westrope Ranches Dick Westrope	Don Greathouse	Stationary	6.7	1	15	3	Contact did not know	18	Middle of Sutter Bypass	In
17A	Akin Ranch Dick Akin	Dick Akin	Stationary	13.7	1	40	4	7,000 (15.6)	16	8 to 10	Out
17B	Josephine Etchevery	John Oji	Stationary	15	1	40	10	2,800 (6.2)	24	5 to 8	Out
17	Akin Ranch Dick Akin	Dick Akin	Stationary	13.7	1	40	4	7,000 (15.6)	16	5 to 8	Out
18	Westrope Ranches Dick Westrope	Don Greathouse	Stationary	34?	1	15	3	Contact did not know	18	About 20	In
20	Montna Properties	Jon Munger	Stationary	34	1	25	5.4	7,275 (16.2)	18	20	In
21	Nordic Industries - K4 Farms	Jens Karlshoej	Stationary	17.82	2	15 & 20	10	5,000 (11.1) 6,000 (13.4)	16 &18	15 to 20	In
22	Nordic Industries - K4 Farms	Jens Karlshoej	Stationary	34?	2	15 & 20	10	5,000 (11.1) 6,000 (13.4)	16 & 16	15 to 20	In
23	Nordic Industries - K4 Farms	Jens Karlshoej	Stationary	12.82	1	15	10	3,800 (8.5) 4,000 (8.9)	18	18 to 20	In
24	Montna Properties	Jon Munger	Stationary	12.82	2	40 & 25	8.6	8,556 (19.1) 4,311 (9.6)	18	10 & 10	In
25	Danna & Danna, Inc Steve Danna	Steve Danna	Stationary		1	25	40	2,200 (4.9)	24	10	Out

Appendix A, Continued

Site	Owner	Pump Information Contact	Water Rights		Pump Characteristics						
			Type Water Right	Maximum Diversion Right, cfs	Number of Pumps at Site	Power, HP	Lift, feet	Approximate Pumping Capacity, GPM (cfs)	Intake Discharge Size, inches	Placement Relative to Edge of Channel, feet	Pumps in or out of Sutter Bypass
1W	Roy Lanza	Roy Lanza	Stationary	Total right of 1.97 & 1.17 cfs for West Canal	1	15	8	1500 (3.3)	14	8	in
2W	Roy Lanza	Roy Lanza	Stationary	Total right of 1.97 & 1.17 cfs for West Canal	1	3	8	300 (0.7)	12	Recessed 7' from bank	in

Appendix B
Survey Data

Appendix B
Survey Data

Whitehead & Associates surveyed the selected diversion sites in the summer of 2002, collecting information on the local topography and key features of the pumps. Over the course of two years, several pumps were added and ownerships changed. Ducks Unlimited, Inc conducted a follow up survey in the fall of 2004 to fill in missing data gaps. The horizontal and vertical datum used for this project is California Zone 2, NAD 1983 and NAVD 1988, respectively. The following sites are contained in this appendix:

Map of Points of Diversion
Pump Site 1
Pump Site 2
Pump Site 5
Pump Site 7
Pump Site 7A
Pump Site 8
Pump Site 12
Pump Site 13
Pump Site 14
Pump Site 15A
Pump Site 15B
Pump Site 15C
Pump Site 16
Pump Site 17
Pump Site 17A
Pump Site 17B
Pump Site 18
Pump Site 19
Pump Site 20
Pump Site 21
Pump Site 22
Pump Site 23
Pump Site 24
Pump Site 25
Pump Site 1W
Pump Site 2W

Appendix C
California Department of Fish and Game
Fish Screening Criteria

STATE OF CALIFORNIA

RESOURCES AGENCY

DEPARTMENT OF FISH AND GAME

FISH SCREENING CRITERIA

June 19, 2000

1. STRUCTURE PLACEMENT

A. Streams And Rivers (flowing water): The screen face shall be parallel to the flow and adjacent bankline (water's edge), with the screen face at or streamward of a line defined by the annual low-flow water's edge.

The upstream and downstream transitions to the screen structure shall be designed and constructed to match the bankline, minimizing eddies upstream of, in front of, and downstream of, the screen.

Where feasible, this "on-stream" fish screen structure placement is preferred by the California Department of Fish and Game.

B. In Canals (flowing water): The screen structure shall be located as close to the river source as practical, in an effort to minimize the approach channel length and the fish return bypass length. This "in canal" fish screen location shall only be used where an "on-stream" screen design is not feasible. This situation is most common at existing diversion dams with headgate structures.

The current National Marine Fisheries Service - Southwest Region criteria for these types of installations shall be used (Attachment A).

C. Small Pumped Diversions: Small pumped diversions (less than 40 cubic-feet per second) which are screened using "manufactured, self-contained" screens shall conform to the National Marine Fisheries Service - Southwest Region criteria (Attachment A).

D. Non-Flowing Waters (tidal areas, lakes and reservoirs): The preferred location for the diversion intake structure shall be offshore, in deep water, to minimize fish contact with the diversion. Other configurations will be considered as exceptions to the screening criteria as described in Section 5.F. below.

2. APPROACH VELOCITY (Local velocity component perpendicular to the screen face

A. Flow Uniformity: The design of the screen shall distribute the approach velocity uniformly across the face of the screen. Provisions shall be made in the design of the screen to allow for adjustment of flow patterns. The intent is to ensure uniform flow distribution through the entire face of the screen as it is constructed and operated.

B. Self-Cleaning Screens: The design approach velocity shall not exceed:

1. Streams and Rivers (flowing waters) - Either:

    a. 0.33 feet per second, where exposure to the fish screen shall not exceed fifteen minutes, or

    b. 0.40 feet per second, for small (less than 40 cubic-feet per second) pumped diversions using "manufactured, self-contained" screens.

2. In Canals (flowing waters) - 0.40 feet per second, with a bypass entrance located every one-minute of travel time along the screen face.

3. Non-Flowing Waters (tidal areas, lakes and reservoirs) - The specific screen approach velocity shall be determined for each installation, based on the species and life stage of fish being protected. Velocities which exceed those described above will require a variance to these criteria (see Section 5.F. below).

(Note: At this time, the U.S. Fish and Wildlife Service has selected a 0.2 feet per second approach velocity for use in waters where the Delta smelt is found. Thus, fish screens in the Sacramento-San Joaquin Estuary should use this criterion for design purposes.)

C. Screens Which Are Not Self-Cleaning: The screens shall be designed with an approach velocity one-fourth that outlined in Section B. above. The screen shall be cleaned before the approach velocity exceeds the criteria described in Section B.

D. Frequency Of Cleaning: Fish screens shall be cleaned as frequently as necessary to prevent flow impedance and violation of the approach velocity criteria. A cleaning cycle once every 5 minutes is deemed to meet this standard.

E. Screen Area Calculation: The required wetted screen area (square feet), excluding the area affected by structural components, is calculated by dividing the **maximum** diverted flow (cubic-feet per second) by the allowable approach velocity (feet per second). Example:

1.0 cubic-feet per second / 0.33 feet per second = 3.0 square feet

Unless otherwise specifically agreed to, this calculation shall be done at the **minimum** stream stage.

3. SWEEPING VELOCITY (Velocity component parallel to screen face)

A. In Streams And Rivers: The sweeping velocity should be at least two times the allowable approach velocity.

B. In Canals: The sweeping velocity shall exceed the allowable approach velocity. Experience has shown that sweeping velocities of 2.0 feet per second (or greater) are preferable.

C. Design Considerations: Screen faces shall be designed flush with any adjacent screen bay piers or walls, to allow an unimpeded flow of water parallel to the screen face.

4. SCREEN OPENINGS

A. Porosity: The screen surface shall have a minimum open area of 27 percent. We recommend the maximum possible open area consistent with the availability of appropriate material, and structural design considerations.

The use of open areas less than 40 percent shall include consideration of increasing the screen surface area, to reduce slot velocities, assisting in both fish protection and screen cleaning.

B. Round Openings: Round openings in the screening shall not exceed 3.96mm (5/32in). In waters where steelhead rainbow trout fry are present, this dimension shall not exceed 2.38mm (3/32in).

C. Square Openings: Square openings in screening shall not exceed 3.96mm (5/32in) measured diagonally. In waters where steelhead rainbow trout fry are present, this dimension shall not exceed 2.38mm (3/32in) measured diagonally.

D. Slotted Openings: Slotted openings shall not exceed 2.38mm (3/32in) in width. In waters where steelhead rainbow trout fry are present, this dimension shall not exceed 1.75mm (0.0689in).

5. SCREEN CONSTRUCTION

A. Material Selection: Screens may be constructed of any rigid material, perforated, woven, or slotted that provides water passage while physically excluding fish. The largest possible screen open area which is consistent with other project requirements should be used. Reducing the screen slot velocity is desirable both to protect fish and to ease cleaning requirements. Care should be taken to avoid the use of materials with sharp edges or projections which could harm fish.

B. Corrosion and Fouling Protection: Stainless steel or other corrosion-resistant material is the screen material recommended to reduce clogging due to corrosion. The use of both active and passive corrosion protection systems should be considered.

Consideration should be given to anti-fouling material choices, to reduce biological fouling problems. Care should be taken not to use materials deemed deleterious to fish and other wildlife.

C. Project Review and Approval: Plans and design calculations, which show that all the applicable screening criteria have been met, shall be provided to the Department before written approval can be granted by the appropriate Regional Manager.

The approval shall be documented in writing to the project sponsor, with copies to both the Deputy Director, Habitat Conservation Division and the Deputy Director, Wildlife and Inland Fisheries Division. Such approval may include a requirement for post-construction evaluation, monitoring and reporting.

D. Assurances: All fish screens constructed after the effective date of these criteria shall be designed and constructed to satisfy the current criteria. Owners of existing screens, approved by the Department prior to the effective date of these criteria, shall not be required to upgrade their facilities to satisfy the current criteria unless:

1. The controlling screen components deteriorate and require replacement (i.e., change the opening size or opening orientation when the screen panels or rotary drum screen coverings need replacing),

2. Relocation, modification or reconstruction (i.e., a change of screen alignment or an increase in the intake size to satisfy diversion requirements) of the intake facilities, or

3. The owner proposes to increase the rate of diversion which would result in violation of the criteria without additional modifications.

E. Supplemental Criteria: Supplemental criteria may be issued by the Department for a project, to accommodate new fish screening technology or to address species-specific or site-specific circumstances.

F. Variances: Written variances to these criteria may be granted with the approval of the appropriate Regional Manager and concurrence from both the Deputy Director, Habitat Conservation Division and the Deputy Director, Wildlife and Inland Fisheries Division. At a minimum, the rationale for the variance must be described and justified in the request.

Evaluation and monitoring may be required as a condition of any variance, to ensure that the requested variance does not result in a reduced level of protection for the aquatic resources.

It is the responsibility of the project sponsor to obtain the most current version of the appropriate fish screen criteria. Project sponsors should contact the Department of Fish and Game, the National Marine Fisheries Service (for projects in marine and anadromous waters) and the U.S. Fish and Wildlife Service (for projects in anadromous and fresh waters) for guidance.

Copies of the current criteria are available from the Department of Fish and Game through the appropriate Regional office, which should be the first point of contact for any fish screening project.

Northern California and North Coast Region; 601 Locust Street, Redding, CA 96001 - (916) 225-2300.

Sacramento Valley and Central Sierra Region; 1701 Nimbus Drive, Rancho Cordova, CA 95670 - (916) 358-2900.

Central Coast Region; 7329 Silverado Trail/P.O. Box 46, Yountville, CA 94599 -(707) 944-5500.

San Joaquin Valley-Southern Sierra Region; 1234 E. Shaw Avenue, Fresno, CA 93710 - (209) 243-4005.

South Coast Region; 4649 View Crest Avenue, San Diego, CA 92123 - (619) 467-4201.

Eastern Sierra and Inland Deserts Region; 4775 Bird Farms Road, Chino Hills, CA 91709 - (909) 597-9823.

Marine Region; 20 Lower Ragsdale Drive, #100, Monterey, CA 93940 - (831) 649-2870.

Technical assistance can be obtained directly from the Habitat Conservation Division; 1416 Ninth Street, Sacramento, CA 95814 - (916) 653-1070.

The current National Marine Fisheries Service criteria are available from their Southwest Region; 777 Sonoma Avenue, Room 325, Santa Rosa, CA 95402 - (707) 575-6050.

California Department of Fish and Game Region Map (PDF, 35KB)

This map is in Adobe PDF format. To view it you must have Adobe Acrobat Reader. If you do not have the reader, click here to download.

Attachment A: National Marine Fisheries Service - Southwest Region Fish Screening Criteria

Appendix D
National Marine Fisheries Service
Fish Screening Criteria

National Marine Fisheries Service
Southwest Region

Fish Screening Criteria
for
Anadromous Salmonids

January 1997

Fish Screening Criteria for Anadromous Salmonids [1]
National Marine Fisheries Service
Southwest Region

January 1997

Table of Contents

[1] Adapted from NMFS, Northwest Region

I. General Considerations

This document provides guidelines and criteria for functional designs of downstream migrant fish passage facilities at hydroelectric, irrigation, and other water withdrawal projects. It is promulgated by the National Marine Fisheries Service (NMFS), Southwest Region as a result of its authority and responsibility for prescribing fishways under the Endangered Species Act (ESA), the Federal Power Act, administered by the Federal Energy Regulatory Commission (FERC), and the Fish and Wildlife Coordination Act (FWCA), administered by the U.S. Fish & Wildlife Service.

The guidelines and criteria are general in nature. There may be cases where site constraints or extenuating circumstances dictate a waiver or modification of one or more of these criteria. Conversely, where there is an opportunity to protect fish, site-specific criteria may be added. Variances from established criteria will be considered on a project-by-project basis.

The swimming ability of fish is a primary consideration in designing a fish screen facility. Research shows that swimming ability varies depending on multiple factors relating to fish physiology, biology, and the aquatic environment. These factors include: species, physiological development, duration of swimming time required, behavioral aspects, physical condition, water quality, temperature, lighting conditions, and many others. Since conditions affecting swimming ability are variable and complex, screen criteria must be expressed in general terms and the specifics of any screen design must address on-site conditions.

NMFS may require project sponsors to investigate site-specific variables critical to the fish screen system design. This investigation may include fish behavioral response to hydraulic conditions, weather conditions (ice, wind, flooding, etc.), river stage-discharge relationships, seasonal operations, sediment and debris problems, resident fish populations, potential for creating predation opportunity, and other pertinent information. The size of salmonids present at a potential screen site usually is not known, and can change from year-to-year based on flow and temperature conditions. Thus, adequate data to describe the size-time relationship requires substantial sampling over a number of years. NMFS will normally assume that fry-sized salmonids are present at all sites unless adequate biological investigation proves otherwise. The burden of proof is the responsibility of the owner of the screen facility.

New facilities which propose to utilize unproven fish protection technology frequently require:

1) development of a biological basis for the concept;
2) demonstration of favorable behavioral responses in a laboratory setting;
3) an acceptable plan for evaluating the prototype installation;
4) an acceptable alternate plan should the prototype not adequately protect fish.

Additional information can be found in *Experimental Fish Guidance Devices*, position statement of the National Marine Fisheries Service, Southwest Region, January 1994.

Striped Bass, Herring, Shad, Cyprinids, and other anadromous fish species may have eggs and/or very small fry which are moved with any water current (tides, streamflows, etc.). Installations where these species are present may require individual evaluation of the proposed project using more conservative screening requirements. In instances where state or local regulatory agencies require more stringent screen criteria to protect species other than salmonids, NMFS will generally defer to the more conservative criteria.

General screen criteria and procedural guidelines are provided below. Specific exceptions to these criteria occur in the design of small screen systems (less than 40 cubic feet per second) and certain small pump intakes. These exceptions are listed in Section K, Modified Criteria for Small Screens, and in the separate addendum entitled: Juvenile Fish Screen Criteria For Pump Intakes, National Marine Fisheries Service, Portland, Oregon, May 9, 1996.

II. General Procedural Guidelines

For projects where NMFS has jurisdiction, such as FERC license applications and ESA consultations, a functional design must be developed as part of the application or consultation. These designs must reflect NMFS design criteria and be acceptable to NMFS. Acceptable designs typically define type, location, method of operation, and other important characteristics of the fish screen facility. Design drawings should show structural dimensions in plan, elevation, and cross-sectional views, along with important component details. Hydraulic information should include: hydraulic capacity, expected water surface elevations, and flows through various areas of the structures. Documentation of relevant hydrologic information is required. Types of materials must be identified where they will directly affect fish. A plan for operations and maintenance procedures should be included- i.e., preventive and corrective maintenance procedures, inspections and reporting requirements, maintenance logs, etc.- particularly with respect to debris, screen cleaning, and sedimentation issues. The final detailed design shall be based on the functional design, unless changes are agreed to by NMFS.

All juvenile passage facilities shall be designed to function properly through the full range of hydraulic conditions expected at a particular project site during fish migration periods, and shall account for debris and sedimentation conditions which may occur.

III. Screen Criteria for Juvenile Salmonids

A. Structure Placement

1. General:

The screened intake shall be designed to withdraw water from the most appropriate elevation, considering juvenile fish attraction, appropriate water temperature control downstream or a combination thereof. The design must accommodate the expected range of water surface elevations.

For on-river screens, it is preferable to keep the fish in the main channel rather than put them through intermediate screen bypasses. NMFS decides whether to require intermediate bypasses for on-river, straight profile screens by considering the biological and hydraulic conditions existing at each individual project site.

2. Streams and Rivers:

Where physically practical, the screen shall be constructed at the diversion entrance. The screen face should be generally parallel to river flow and aligned with the adjacent bankline. A smooth transition between the bankline and the screen structure is important to minimize eddies and undesirable flow patterns in the vicinity of the screen. If trash racks are used, sufficient hydraulic gradient is required to route juvenile fish from between the trashrack and screens to safety. Physical factors that may preclude screen construction at the diversion entrance include excess river gradient, potential for damage by large debris, and potential for heavy sedimentation. Large stream-side installations may require intermediate bypasses along the screen face to prevent excessive exposure time. The need for intermediate bypasses shall be decided on a case-by-case basis.

2. Canals:

Where installation of fish screens at the diversion entrance is undesirable or impractical, the screens may be installed at a suitable location downstream of the canal entrance. All screens downstream of the diversion entrance shall provide an effective juvenile bypass system- designed to collect juvenile fish and safely transport them back to the river with minimum delay. The angle of the screen to flow should be adequate to effectively guide fish to the bypass. Juvenile bypass systems are part of the overall screen system and must be accepted by NMFS.

3. Lakes, Reservoirs, and Tidal Areas:

a. Where possible, intakes should be located off shore to minimize fish contact with the facility. Water velocity from any direction toward the screen shall not exceed the allowable approach velocity. Where possible, locate intakes where sufficient sweeping velocity exists. This minimizes sediment accumulation in and around the screen, facilitates debris removal, and encourages fish movement away from the screen face.

b. If a screened intake is used to route fish past a dam, the intake shall be designed to withdraw water from the most appropriate elevation in order to provide the best juvenile fish attraction to the bypass channel as well as to achieve appropriate water temperature control downstream. The entire range of forebay fluctuations shall be accommodated by the design, unless otherwise approved by NMFS.

B. Approach Velocity

Definition: *Approach Velocity* is the water velocity vector component perpendicular to the screen face.

Approach velocity shall be measured approximately three inches in front of the screen surface.

1. Fry Criteria - less than 2.36 inches {60 millimeters (mm)} in length.

If a biological justification cannot demonstrate the absence of fry-sized salmonids in the vicinity of the screen, fry will be assumed present and the following criteria apply:

Design approach velocity shall not exceed-

Streams and Rivers:	0.33 feet per second
Canals:	0.40 feet per second
Lakes, Reservoirs, Tidal:	0.33 feet per second (salmonids) [2]

2. Fingerling Criteria - 2.36 inches {60 mm} and longer

If biological justification can demonstrate the absence of fry-sized salmonids in the vicinity of the screen, the following criteria apply:

Design approach velocity shall not exceed -
All locations: 0.8 feet per second

[2] Other species may require different approach velocity standards, e.g.- in California, the U.S. Fish & Wildlife Service requires 0.2 fps approach velocity where delta smelt are present in the tidal areas of the San Francisco Bay estuary.

3. The *total submerged screen area required* (excluding area of structural components) is calculated by dividing the maximum diverted flow by the allowable approach velocity. (Also see Section K, Modified Criteria for Small Screens, part 1).

4. The screen design must provide for uniform flow distribution over the surface of the screen, thereby minimizing approach velocity. This may be accomplished by providing adjustable porosity control on the downstream side of the screens, unless it can be shown unequivocally (such as with a physical hydraulic model study) that localized areas of high velocity can be avoided at all flows.

C. Sweeping Velocity

Definition: *Sweeping Velocity* is the water velocity vector component parallel and adjacent to the screen face.

1. Sweeping Velocity shall be greater than approach velocity. For canal installations, this is accomplished by angling screen face less than 45° relative to flow (see Section K, Modified Criteria for Small Screens). This angle may be dictated by specific canal geometry, or hydraulic and sediment conditions.

D. Screen Face Material

1. Fry criteria

If a biological justification cannot demonstrate the absence of fry-sized salmonids in the vicinity of the screen, fry will be assumed present and the following criteria apply for screen material:

a. Perforated plate: screen openings shall not exceed 3/32 inches (2.38 mm), measured in diameter.

b. Profile bar: screen openings shall not exceed 0.0689 inches (1.75 mm) in width.

c. Woven wire: screen openings shall not exceed 3/32 inches (2.38 mm), measured diagonally. (e.g.: 6-14 mesh)

d. Screen material shall provide a minimum of 27% open area.

2. Fingerling Criteria

If biological justification can demonstrate the absence of fry-sized salmonids in the vicinity of the screen, the following criteria apply for screen material:

a. Perforated plate: Screen openings shall not exceed 1/4 inch (6.35 mm) in diameter.

b. Profile bar: screen openings shall not exceed 1/4 inch (6.35 mm) in width

c. Woven wire: Screen openings shall not exceed 1/4 inch (6.35 mm) in the narrow direction

d. Screen material shall provide a minimum of 40% open area.

3. The screen material shall be corrosion resistant and sufficiently durable to maintain a smooth and uniform surface with long term use.

E. Civil Works and Structural Features

1. The face of all screen surfaces shall be placed flush with any adjacent screen bay, pier noses, and walls, allowing fish unimpeded movement parallel to the screen face and ready access to bypass routes.

2. Structural features shall be provided to protect the integrity of the fish screens from large debris. Trash racks, log booms, sediment sluices, or other measures may be needed. A reliable on-going preventive maintenance and repair program is necessary to ensure facilities are kept free of debris and the screen mesh, seals, drive units, and other components are functioning correctly.

3. Screens located in canals - surfaces shall be constructed at an angle to the approaching flow, with the downstream end terminating at the bypass system entrance.

4. The civil works design shall attempt to eliminate undesirable hydraulic effects (e.g.- eddies, stagnant flow zones) that may delay or injure fish, or provide predator opportunities. Upstream training wall(s), or some acceptable variation thereof, shall be utilized to control hydraulic conditions and define the angle of flow to the screen face. Large facilities may require hydraulic monitoring to identify and correct areas of concern.

F. Juvenile Bypass System Layout

Juvenile bypass systems are water channels which transport juvenile fish from the face of a screen to a relatively safe location in the main migratory route of the river or stream. Juvenile bypass systems are necessary for screens located in canals because anadromous fish must be routed back to their main migratory route. For other screen locations and configurations, NMFS accepts the option which, in its judgement, provides the highest degree of fish protection given existing site and project constraints.

1. The screen and bypass shall work in tandem to move out-migrating salmonids (including adults) to the bypass outfall with minimum injury or delay. Bypass entrance(s) shall be designed such that out-migrants can easily locate and enter them. Screens installed in canal diversions shall be constructed with the downstream end of the screen terminating at a bypass entrance. Multiple bypass entrances (intermediate bypasses) shall be employed if the sweeping velocity will not move fish to the bypass within 60 seconds [3] assuming the fish are transported at this velocity. Exceptions will be made for sites without satisfactory hydraulic conditions, or for screens built on river banks with satisfactory river conditions.

2. All components of the bypass system, from entrance to outfall, shall be of sufficient hydraulic capacity to minimize the potential for debris blockage.

3. To improve bypass collection efficiency for a single bank of vertically oriented screens, a bypass training wall may be located at an angle to the screens.

4. In cases where insufficient flow is available to satisfy hydraulic requirements at the main bypass entrance(s), a *secondary screen* may be required. Located in the main screen's bypass channel, a secondary screen allows the prescribed bypass flow to be used to effectively attract fish into the bypass entrance(s) while allowing all but a reduced residual bypass flow to be routed back (by pump or gravity) for the primary diversion use. The residual bypass flow (not passing through the secondary screen) then conveys fish to the bypass outfall location or other destination.

5. Access is required at locations in the bypass system where debris accumulation may occur.

6. The screen civil works floor shall allow fish to be routed to the river safely in the event the canal is dewatered. This may entail a sumped drain with a small gate and drain pipe, or similar provisions.

G. Bypass Entrance

1. Each bypass entrance shall be provided with independent flow control, acceptable to NMFS.

2. Bypass entrance velocity must equal or exceed the maximum velocity vector resultant along the screen, upstream of the entrance. A gradual and efficient acceleration into the bypass is required to minimize delay of out-migrants.

---

[3] In California, 60 second exposure time applies to screens in canals, using a 0.4 fps approach velocity. Where more conservative approach velocities are used, longer exposure times may be approved on a case-by-case basis, and exceptions to established criteria shall be treated as variances.

3. Ambient lighting conditions are required from the bypass entrance to the bypass flow control.

4. The bypass entrance must extend from floor to water surface.

H. Bypass Conduit Design

1. Smooth interior pipe surfaces and conduit joints shall be required to minimize turbulence, debris accumulation, and the risk of injury to juvenile fish. Surface smoothness must be acceptable to the NMFS.

2. Fish shall not free-fall within a confined shaft in a bypass system.

3. Fish shall not be pumped within the bypass system.

4. Pressure in the bypass pipe pipe shall be equal to or above atmospheric pressure.

5. Extreme bends shall be avoided in the pipe layout to avoid excessive physical contact between small fish and hard surfaces and to minimize debris clogging . Bypass pipe centerline radius of curvature (R/D) shall be 5 or greater. Greater R/D may be required for supercritical velocities.

6. Bypass pipes or open channels shall be designed to minimize debris clogging and sediment deposition and to facilitate cleaning. Pipe diameter shall be 24 inches (0.610 m) or greater and pipe velocity shall be 2.0 fps (0.610 mps) or greater, unless otherwise approved by NMFS. (See *Modified Criteria for Small Screens*) for the entire operational range.

7. No closure valves are allowed within bypass pipes.

8. Depth of flow in a bypass conduit shall be 0.75 ft. (0.23 m) or greater, unless otherwise authorized by NMFS (See Modified Criteria for Small Screens).

9. Bypass system sampling stations shall not impair normal operation of the screen facility.

10. No hydraulic jumps should exist within the bypass system.

I. Bypass Outfall

1. Ambient river velocities at bypass outfalls should be greater than 4.0 fps (1.2 mps), or as close as obtainable.

2. Bypass outfalls shall be located and designed to minimize avian and aquatic predation in areas free of eddies, reverse flow, or known predator habitat.

3. Bypass outfalls shall be located where there is sufficient depth (depending on the impact velocity and quantity of bypass flow) to avoid fish injuries at all river and bypass flows.

4. Impact velocity (including vertical and horizontal components) shall not exceed 25.0 fps (7.6 mps).

5. Bypass outfall discharges shall be designed to avoid adult attraction or jumping injuries.

J. Operations and Maintenance

1. Fish Screens shall be automatically cleaned as frequently as necessary to prevent accumulation of debris. The cleaning system and protocol must be effective, reliable, and satisfactory to NMFS. Proven cleaning technologies are preferred.

2. Open channel intakes shall include a trash rack in the screen facility design which shall be kept free of debris. In certain cases, a satisfactory profile bar screen design can substitute for a trash rack.

3. The head differential to trigger screen cleaning for intermittent type systems shall be a maximum of 0.1 feet (.03 m), unless otherwise agreed to by NMFS.

4. The completed screen and bypass facility shall be made available for inspection by NMFS, to verify compliance with design and operational criteria.

5. Screen and bypass facilities shall be evaluated for biological effectiveness and to verify that hydraulic design objectives are achieved.

K. Modified Criteria for Small Screens (Diversion Flow less than 40 cfs)

The following criteria vary from the standard screen criteria listed above. These criteria specifically apply to lower flow, surface-oriented screens (e.g.- small rotating drum screens). Forty cfs is the approximate cut off; however, some smaller diversions may be required to apply the general criteria listed above, while some larger diversions may be allowed to use the “small screen” criteria below. NMFS will decide on a case-by-case basis depending on site constraints.

1. The required screen area is a function of the approach velocity listed in Section B, Approach Velocity, Parts 1, 2, and 3 above. Note that “maximum” refers to the greatest flow diverted, not necessarily the water right.

2. Screen Orientation:

   a. For screen lengths six feet or less, screen orientation may be angled perpendicular to the flow.

b. For screen lengths greater than six feet, screen-to-flow angle must be less than 45 degrees. (See Section C Sweeping Velocity, part 1).

c. For drum screens, design submergence shall be 75% of drum diameter. Submergence shall not exceed 85%, nor be less than 65% of drum diameter.

d. Minimum bypass pipe diameter shall be 10 in (25.4 cm), unless otherwise approved by NMFS.

e. Minimum pipe depth is 1.8 in (4.6 cm) and is controlled by designing the pipe gradient for minimum bypass flow.

Questions concerning this document can be directed to NMFS Hydraulic Engineering Staff at:

National Marine Fisheries Service
Southwest Region
777 Sonoma Ave. Room 325
Santa Rosa, CA 95402
Phone: 707-575-6050

Adopted,

Date: 24 Feb 97

Authorizing Signature:

Pumps on the East Borrow Channel
Site No. 1

Pumps on the East Borrow Channel
Site No. 2

Pumps on the East Borrow Channel
Site No. 5

Pumps on the East Borrow Channel
Site No. 7

Pumps on the East Borrow Channel
Site No. 7A

Pumps on the East Borrow Channel
Site No. 8

Pumps on the East Borrow Channel

Site No. 12

Pumps on the East Borrow Channel

Site No. 13

Pumps on the East Borrow Channel

Site No. 14

Pumps on the East Borrow Channel

Site No. 15A

Pumps on the East Borrow Channel

Site No. 15B

Pumps on the East Borrow Channel

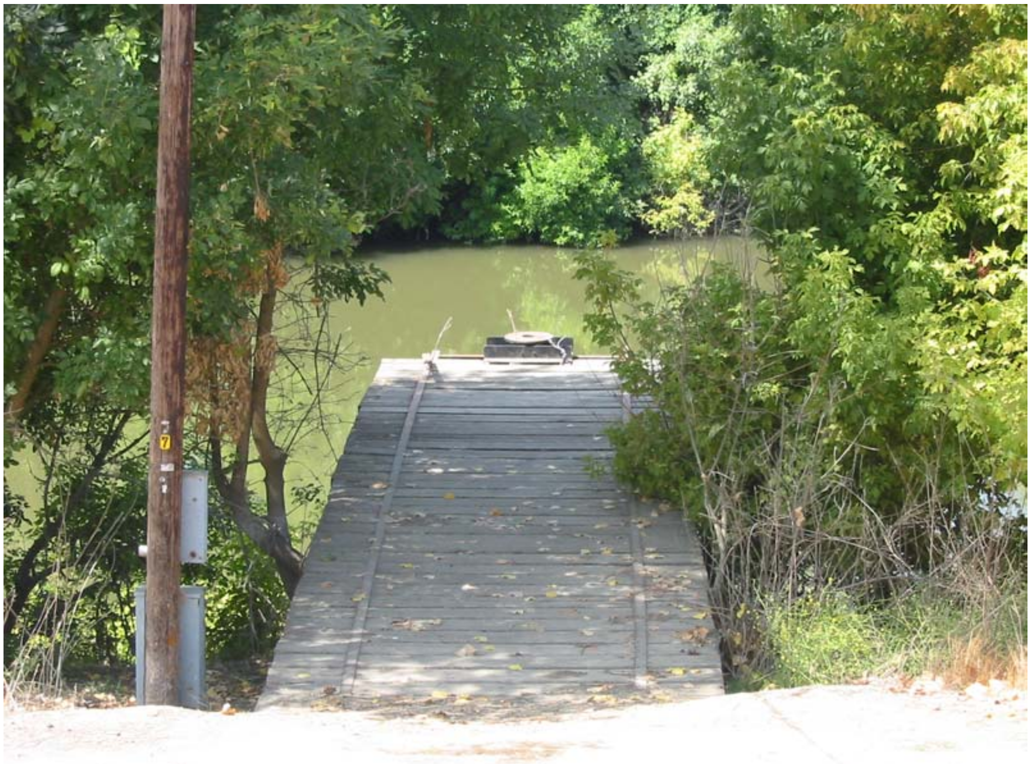
Site No. 15C

Pumps on the East Borrow Channel

Site No. 16

Pumps on the East Borrow Channel

Site No. 17A



Pumps on the East Borrow Channel

Site No. 17B

Pumps on the East Borrow Channel

Site No. 17

Pumps on the East Borrow Channel

Site No. 18

Pumps on the East Borrow Channel

Site No. 19

Pumps on the East Borrow Channel
Site No. 20

Pumps on the East Borrow Channel
Site No. 21

Pumps on the East Borrow Channel

Site No. 22

Pumps on the East Borrow Channel

Site No. 23

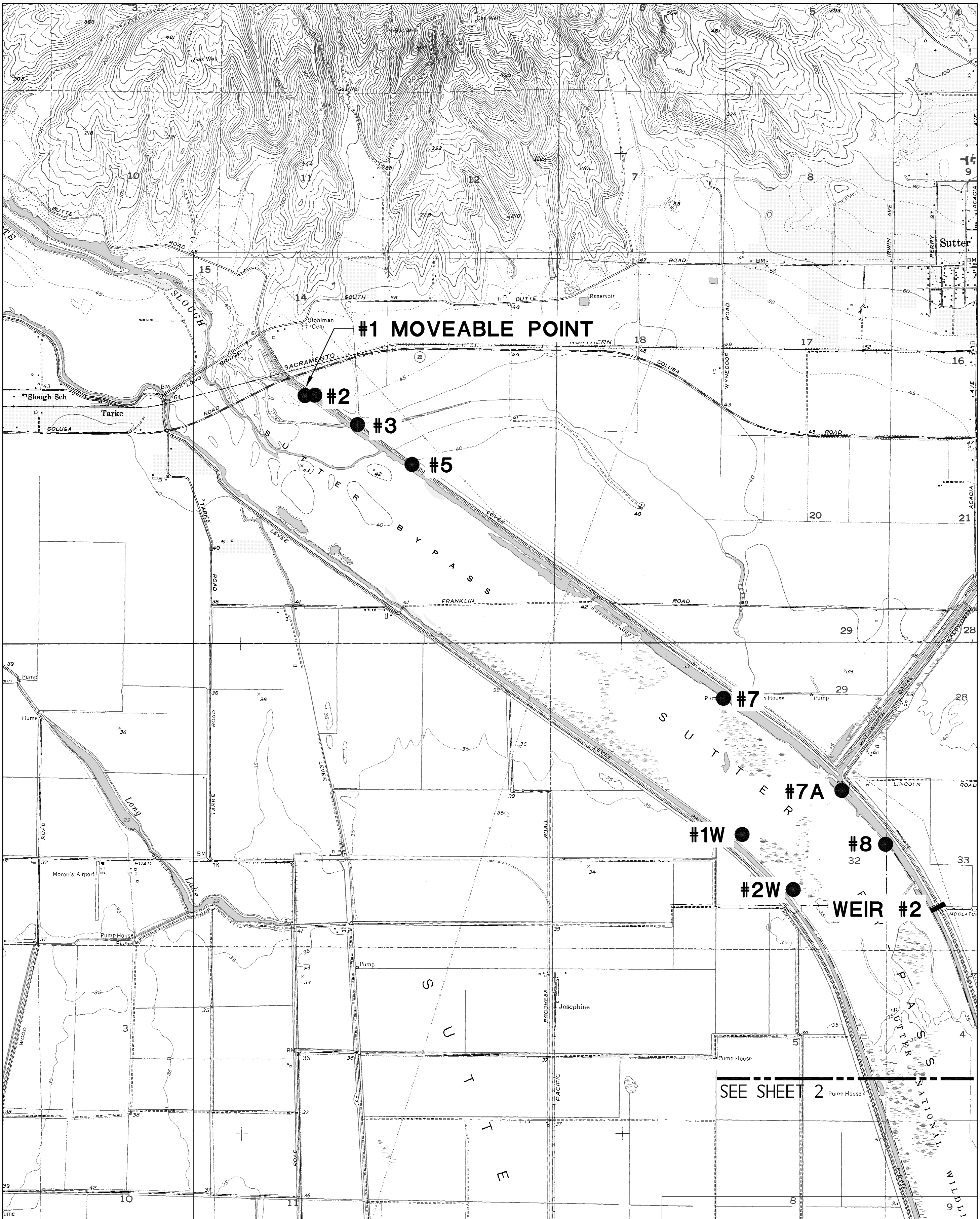
Pumps on the East Borrow Channel

Site No. 24

Pumps on the East Borrow Channel
Site No. 25

Pumps on the West Borrow Channel
Site No. 1W

Pumps on the West Borrow Canal
Site No. 2W



N

BAR SCALE

0 4000 8000

SCALE: 1"=4000'

DUCKS UNLIMITED INC.

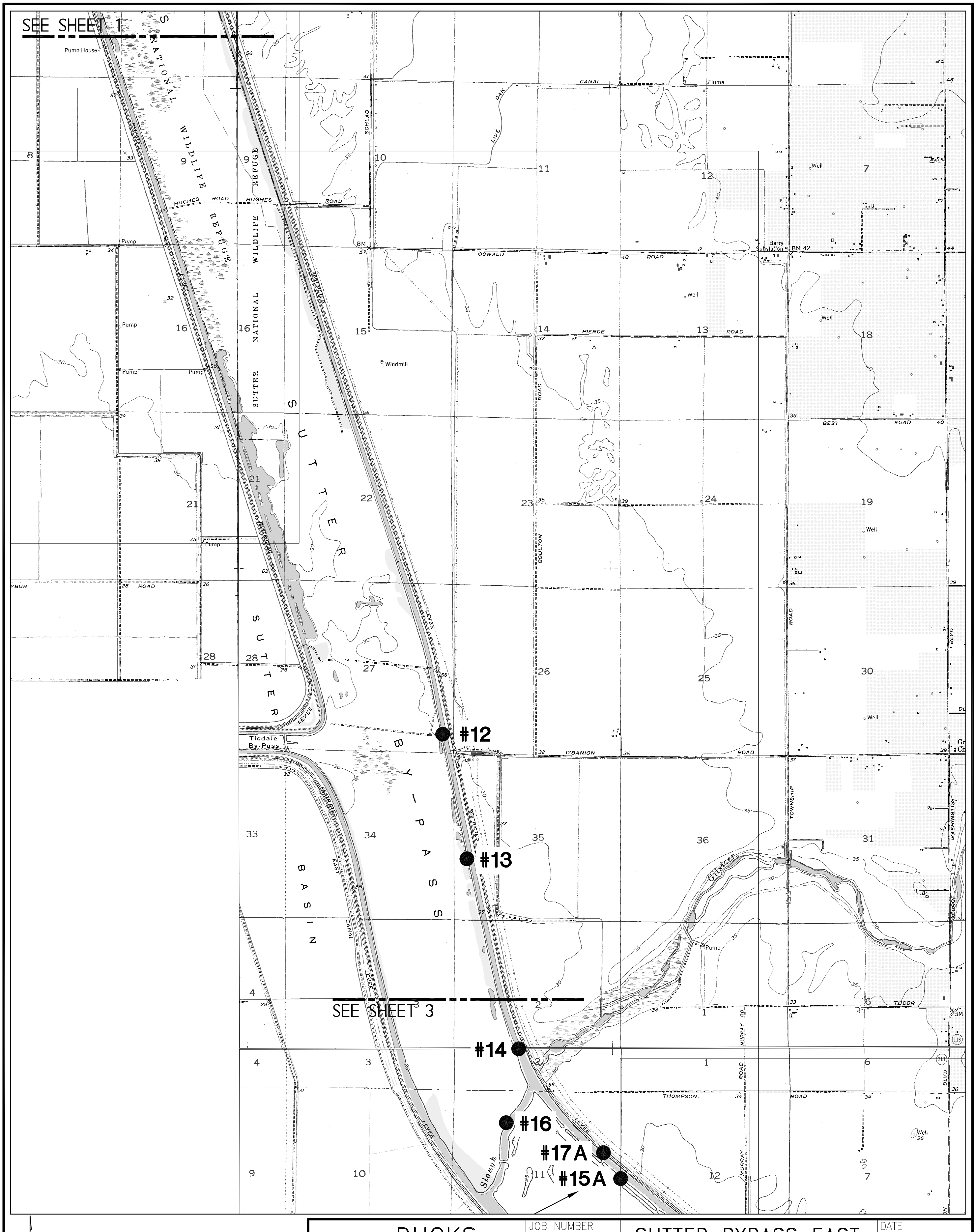
WESTERN REGIONAL OFFICE

JOB NUMBER	CA-0181-001
SURVEYED BY	C WHITEHEAD
DRAFTED BY:	LKW
APPROVED BY:	CB

SUTTER BYPASS EAST BORROW CANAL PUMPS POINTS OF DIVERSION

DATE 10.15.04

SHEET NO 1 -OF- 4



DUCKS UNLIMITED INC.

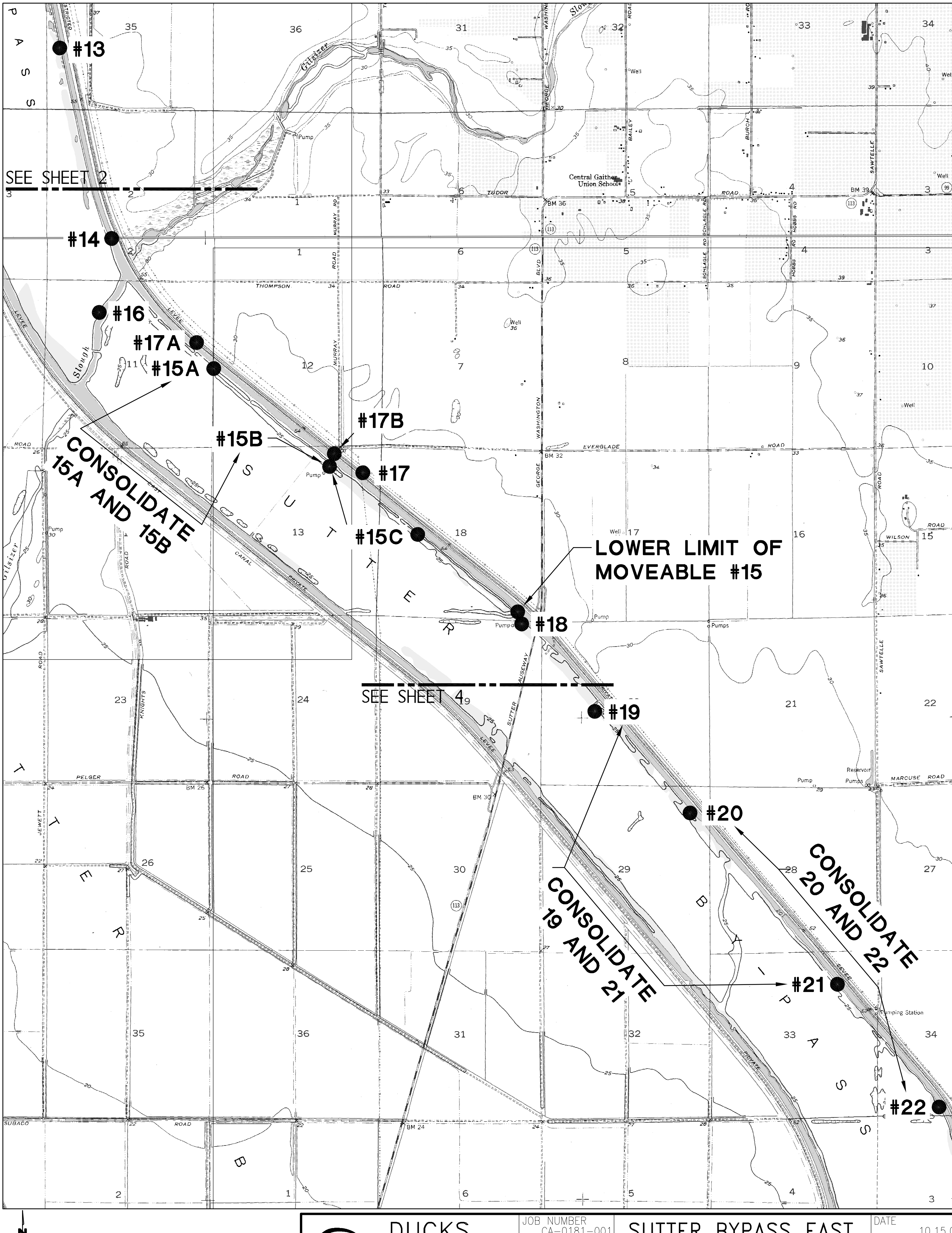
WESTERN REGIONAL OFFICE

JOB NUMBER	CA-0181-001
SURVEYED BY	C WHITEHEAD
DRAFTED BY:	LKW
APPROVED BY:	CB

SUTTER BYPASS EAST BORROW CANAL PUMPS POINTS OF DIVERSION

DATE 10.15.04

SHEET NO 2 -OF- 4



DUCKS UNLIMITED INC.

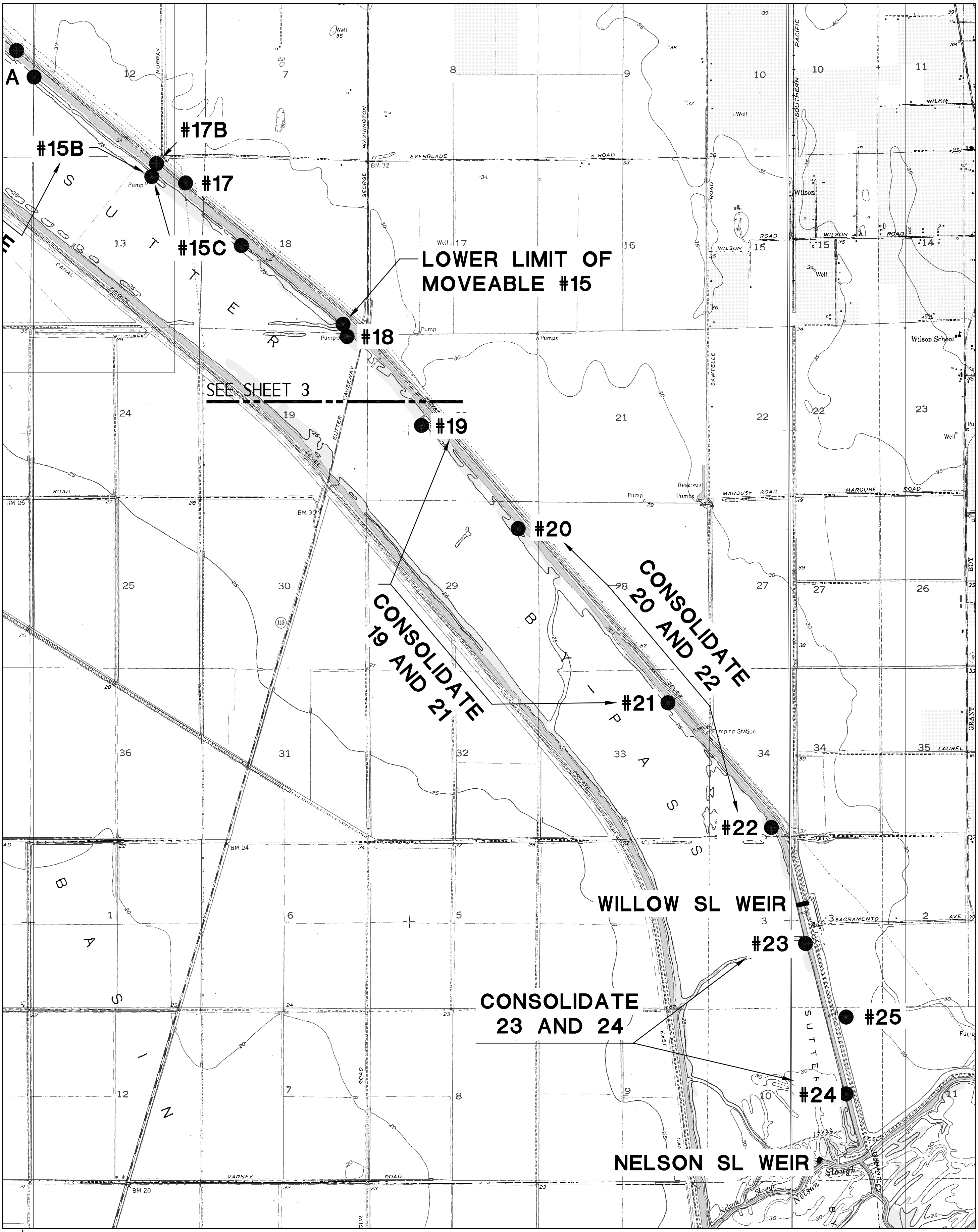
WESTERN REGIONAL OFFICE

JOB NUMBER	CA-0181-001
SURVEYED BY	C WHITEHEAD
DRAFTED BY:	LKW
APPROVED BY:	CB

SUTTER BYPASS EAST BORROW CANAL PUMPS POINTS OF DIVERSION

DATE 10.15.04

SHEET NO 3 -OF- 4



N

BAR SCALE

0 4000 8000

SCALE: 1"=4000'

DUCKS UNLIMITED INC.

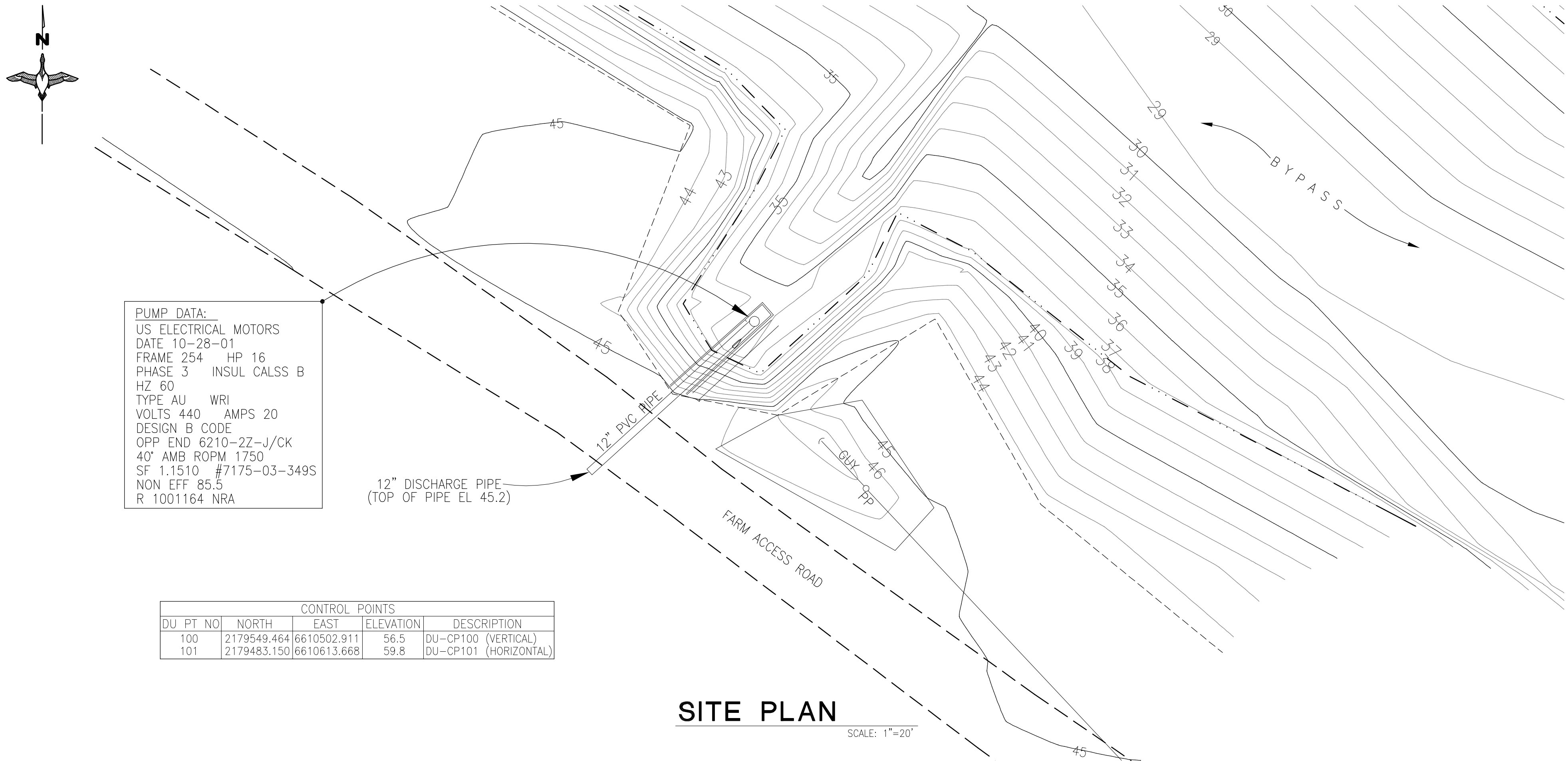
WESTERN REGIONAL OFFICE

JOB NUMBER	CA-0181-001
SURVEYED BY	C WHITEHEAD
DRAFTED BY:	LKW
APPROVED BY:	CB

SUTTER BYPASS EAST BORROW CANAL PUMPS POINTS OF DIVERSION

DATE 10.15.04

SHEET NO 4 -OF- 4

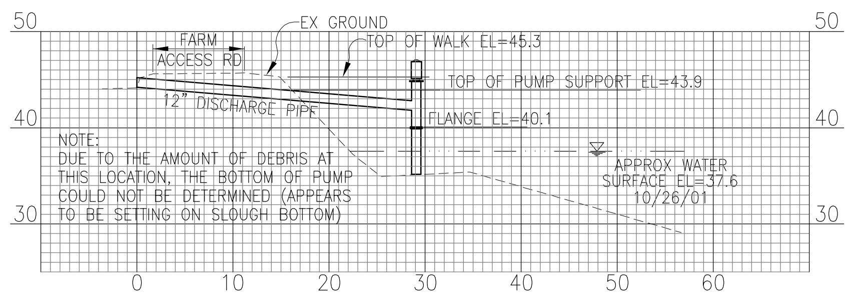


PUMP DATA:
US ELECTRICAL MOTORS
DATE 10-28-01
FRAME 254 HP 16
PHASE 3 INSUL CALSS B
HZ 60
TYPE AU WRI
VOLTS 440 AMPS 20
DESIGN B CODE
OPP END 6210-2Z-J/CK
40° AMB ROPM 1750
SF 1.1510 #7175-03-349S
NON EFF 85.5
R 1001164 NRA

CONTROL POINTS				
DU PT NO	NORTH	EAST	ELEVATION	DESCRIPTION
100	2179549.464	6610502.911	56.5	DU-CP100 (VERTICAL)
101	2179483.150	6610613.668	59.8	DU-CP101 (HORIZONTAL)

SITE PLAN

SCALE: 1"=20'



NOTE:
DUE TO THE AMOUNT OF DEBRIS AT THIS LOCATION, THE BOTTOM OF PUMP COULD NOT BE DETERMINED (APPEARS TO BE SETTING ON SLOUGH BOTTOM)

SECTION AT PUMP NO 1

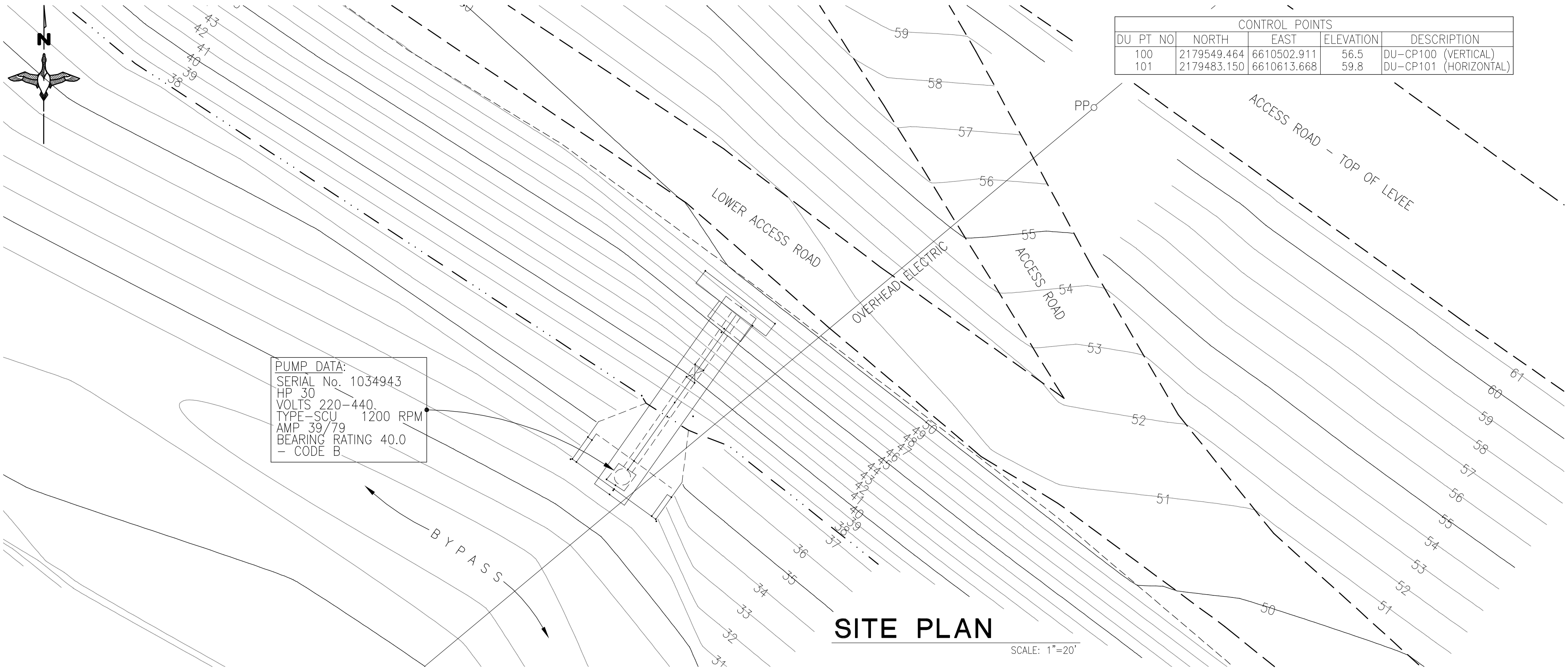
SCALE: 1"=20' HOR AND VER

BAR SCALE

SCALE: 1"=20'

DUCKS UNLIMITED INC.
WESTERN REGIONAL OFFICE

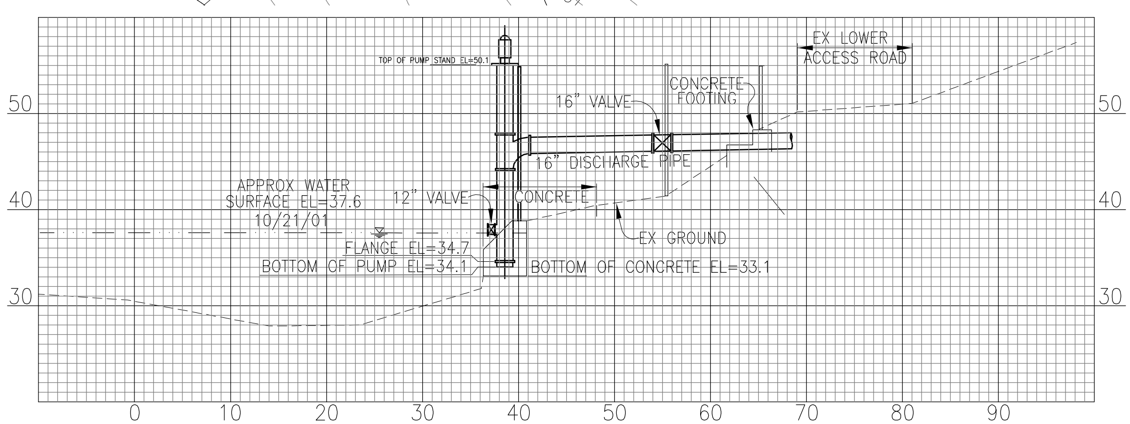
JOB NUMBER CA-0181-001	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 1	DATE 10.15.04
SURVEYED BY C WHITEHEAD		SHEET NO 1 -OF- 1
DRAFTED BY: LKW		
APPROVED BY: CB		



CONTROL POINTS				
DU PT NO	NORTH	EAST	ELEVATION	DESCRIPTION
100	2179549.464	6610502.911	56.5	DU-CP100 (VERTICAL)
101	2179483.150	6610613.668	59.8	DU-CP101 (HORIZONTAL)

SITE PLAN

SCALE: 1"=20'



SECTION AT PUMP NO 2

SCALE: 1"=20' HOR AND VER

BAR SCALE

0 20 40 60

SCALE: 1"=20'

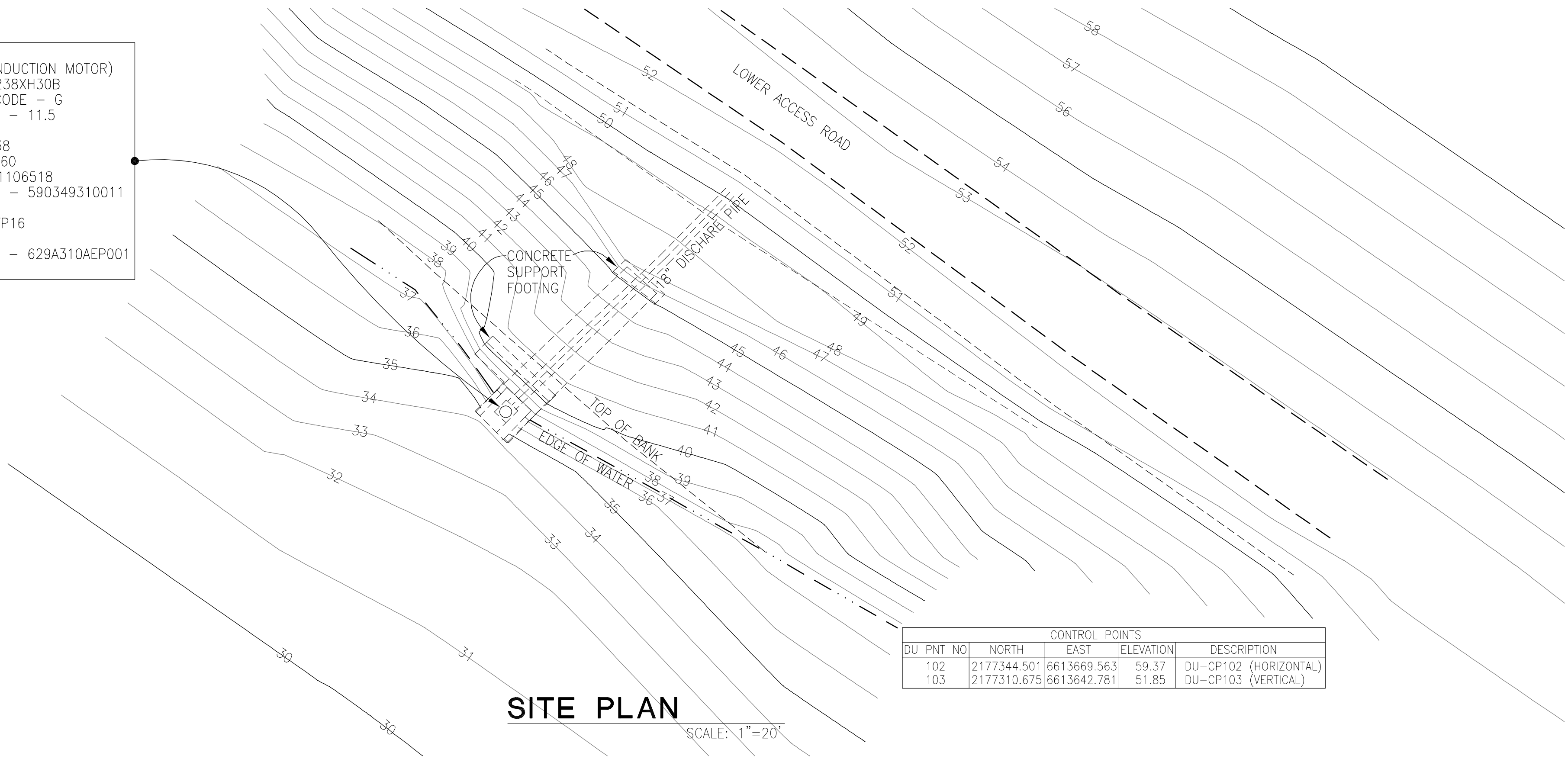
DUCKS UNLIMITED INC.
WESTERN REGIONAL OFFICE

JOB NUMBER CA-0181-001
SURVEYED BY C WHITEHEAD
DRAFTED BY: LKW
APPROVED BY: CB

SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 2

DATE 10.15.04
SHEET NO 1 -OF- 1

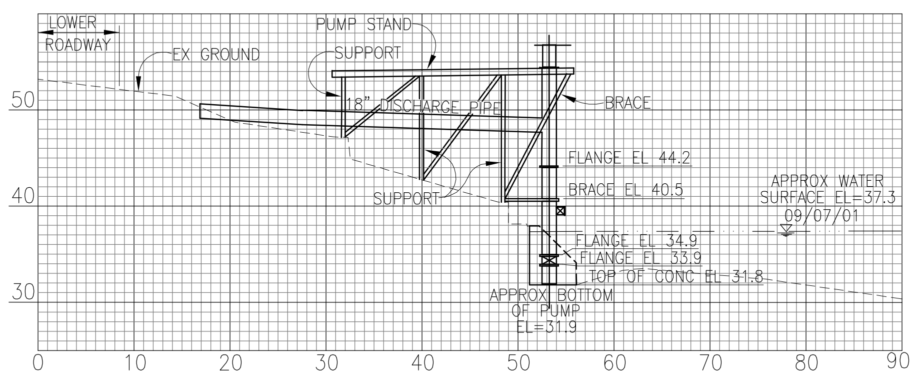
PUMP DATA:
G.E. MOTOR (INDUCTION MOTOR)
MODEL NO 5K6238XH30B
TYPE – K CODE – G
SERVICE FACTOR – 11.5
VOLTS 230/460
FL AMP – 76/38
FL SPEED – 1760
SERIAL No. LKB1106518
UPPER BRG CAT – 590349310011
HP – 30
FRAME – B286TP16
CYCLES – 60
LOWER BRG CAT – 629A310AEP001
SAN JOSE, CA



CONTROL POINTS				
DU PNT NO	NORTH	EAST	ELEVATION	DESCRIPTION
102	2177344.501	6613669.563	59.37	DU–CP102 (HORIZONTAL)
103	2177310.675	6613642.781	51.85	DU–CP103 (VERTICAL)

SITE PLAN

SCALE: 1"=20'



SECTION AT PUMP 5

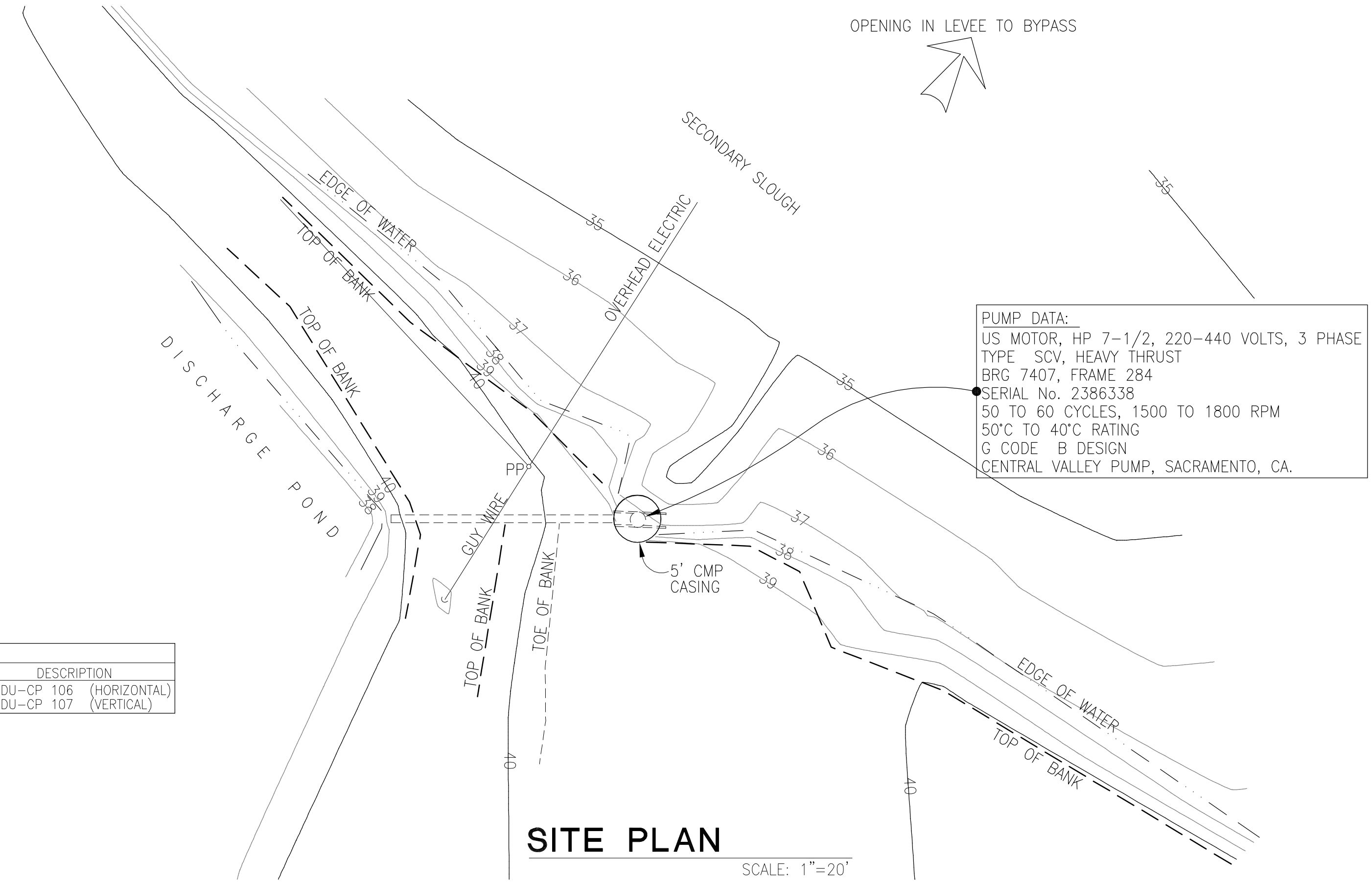
SCALE: 1"=20' HOR AND VER

BAR SCALE

0 20 40 60

SCALE: 1"=20'

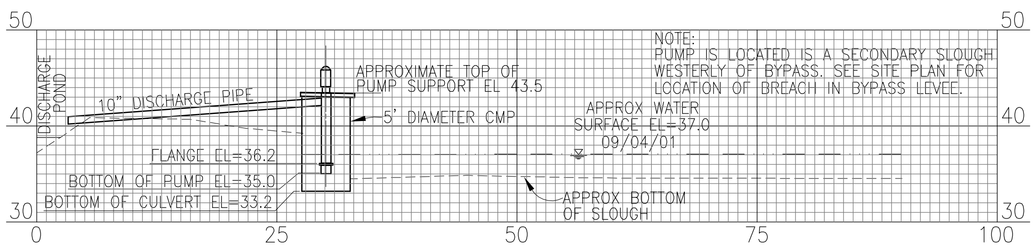
DUCKS UNLIMITED INC. WESTERN REGIONAL OFFICE	JOB NUMBER CA–0181–001	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 5	DATE 10.15.04
	SURVEYED BY C WHITEHEAD		SHEET NO 1 –OF– 1
	DRAFTED BY: LKW		
	APPROVED BY: CB		



CONTROL POINTS				
DU PNT NO	NORTH	EAST	ELEVATION	DESCRIPTION
106	2169833.686	6623632.760	41.1	DU-CP 106 (HORIZONTAL)
107	2169824.460	6623686.279	40.2	DU-CP 107 (VERTICAL)

SITE PLAN

SCALE: 1"=20'



SECTION AT PUMP No. 7

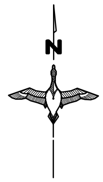
SCALE: 1"=20' HOR AND VER

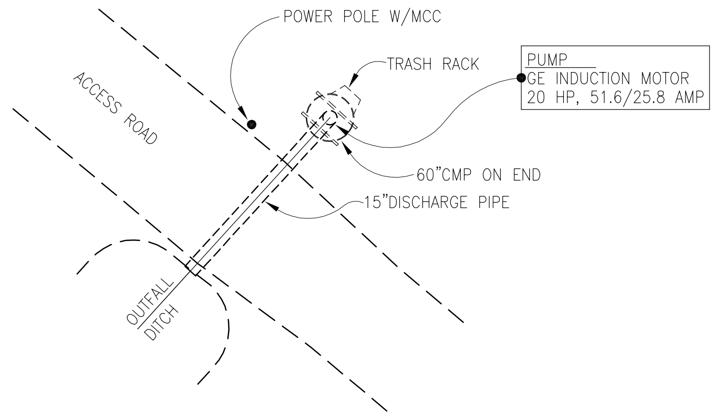
BAR SCALE

0 20 40 60

SCALE: 1"=20'

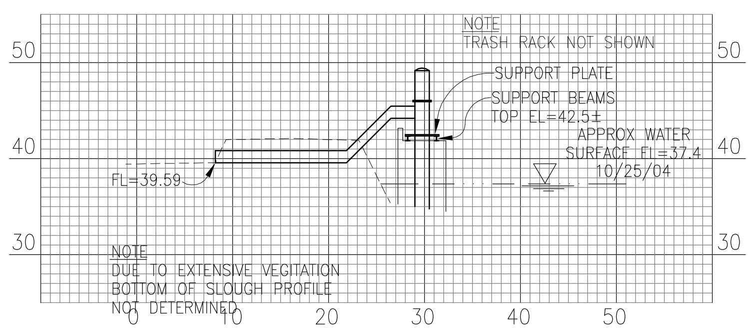
DUCKS UNLIMITED INC. WESTERN REGIONAL OFFICE	JOB NUMBER CA-0181-001 SURVEYED BY C WHITEHEAD DRAFTED BY: LKW APPROVED BY: CB	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 7	DATE 10.15.04 SHEET NO 1 -OF- 1





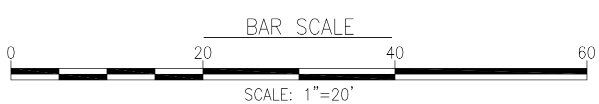
SITE PLAN

SCALE: 1"=20'

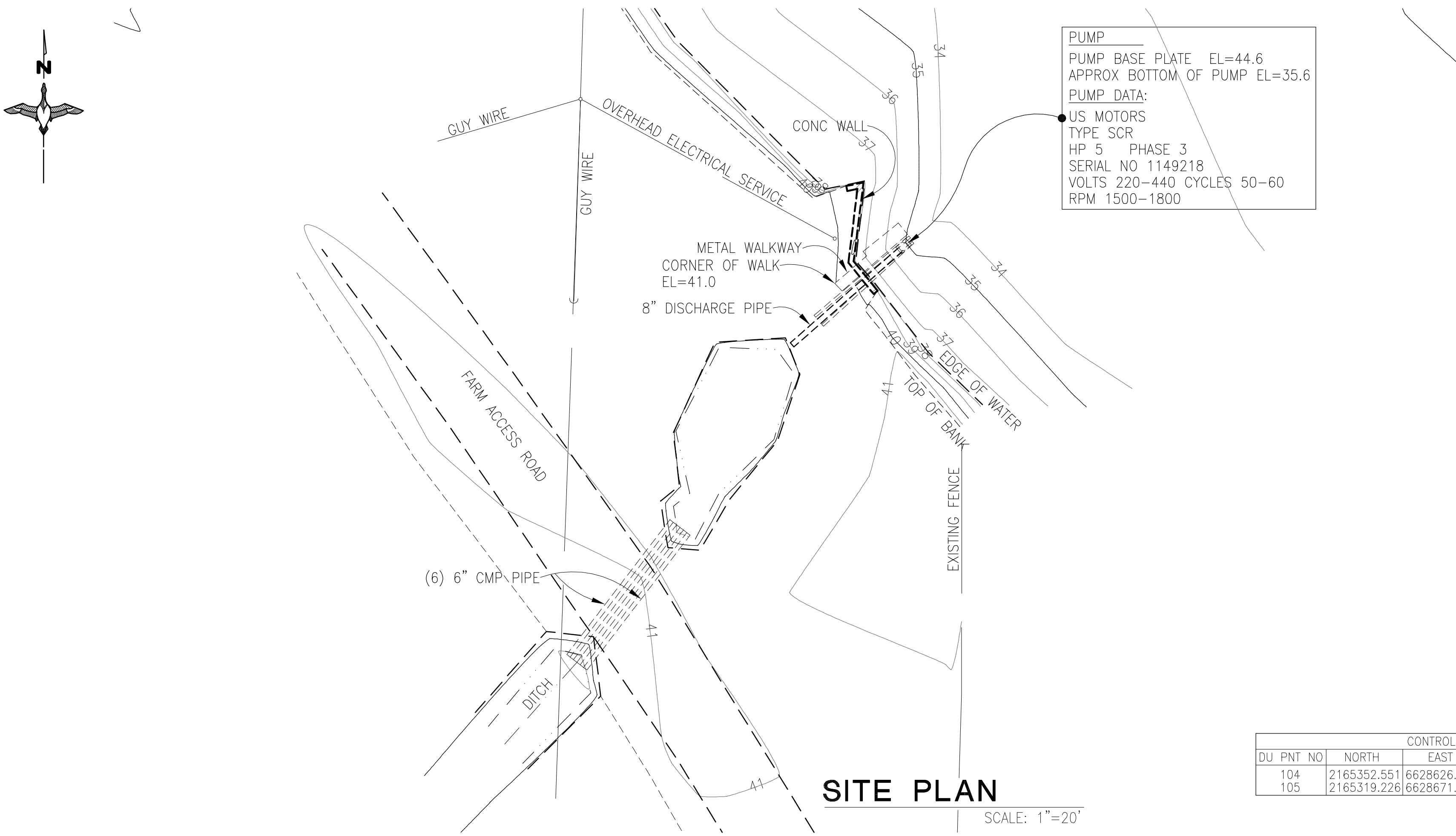


SECTION AT PUMP 7A

SCALE: 1"=20' HOR AND VER

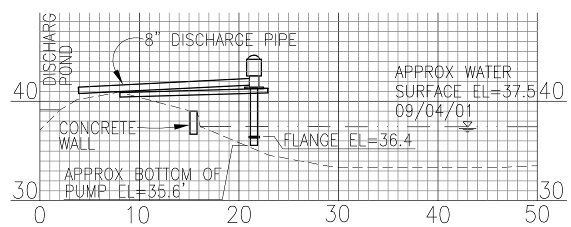


DUCKS UNLIMITED INC. WESTERN REGIONAL OFFICE	JOB NUMBER CA-0181-001 SURVEYED BY C WHITEHEAD DRAFTED BY: LKW APPROVED BY: CB	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 7A	DATE 10.15.04 SHEET NO 1 -OF- 1



SITE PLAN

SCALE: 1"=20'



SECTION AT PUMP NO 8

SCALE: 1"=20' HOR AND VER

CONTROL POINTS				
DU PNT NO	NORTH	EAST	ELEVATION	DESCRIPTION
104	2165352.551	6628626.195	40.7	DU-CP104 (VERTICAL)
105	2165319.226	6628671.795	40.9	DU-CP105 (HORIZONTAL)

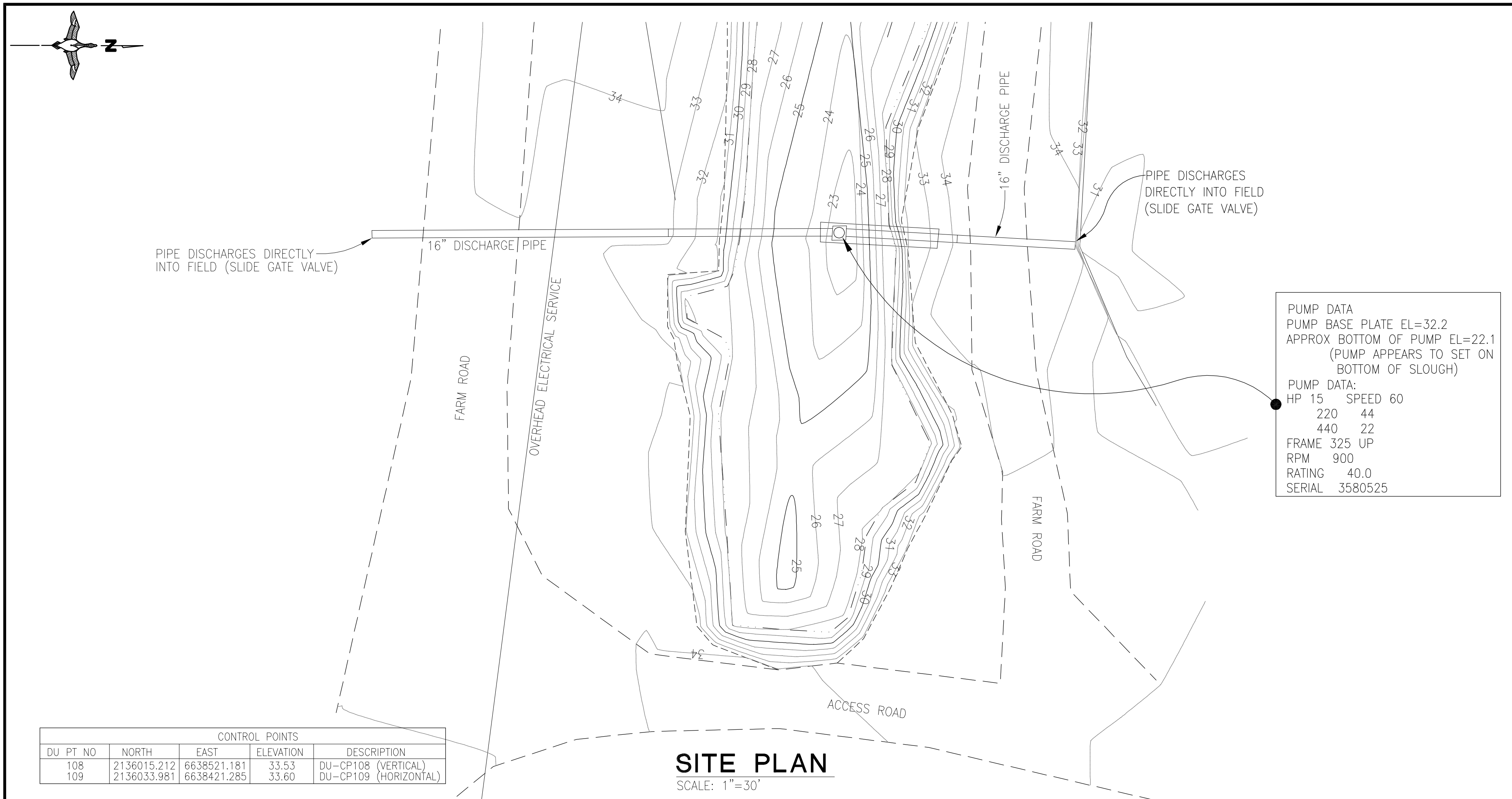
BAR SCALE

0 20 40 60

SCALE: 1"=20'

DUCKS UNLIMITED INC.
WESTERN REGIONAL OFFICE

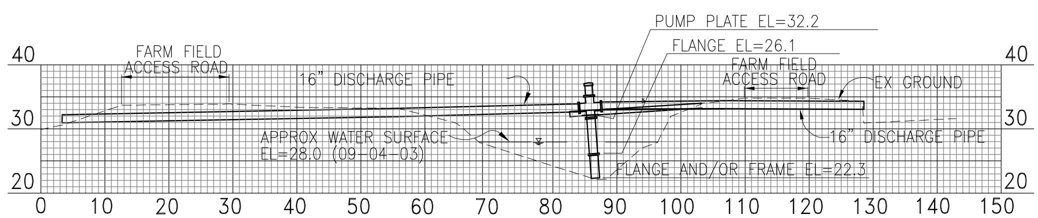
JOB NUMBER CA-0181-001	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 8	DATE 10.15.04	
SURVEYED BY C WHITEHEAD		SHEET NO 1 -OF- 1	
DRAFTED BY: LKW			
APPROVED BY: CB			



CONTROL POINTS				
DU PT NO	NORTH	EAST	ELEVATION	DESCRIPTION
108	2136015.212	6638521.181	33.53	DU-CP108 (VERTICAL)
109	2136033.981	6638421.285	33.60	DU-CP109 (HORIZONTAL)

SITE PLAN

SCALE: 1"=30'



SECTION AT PUMP NO 12

SCALE: 1"=30' HOR AND VER

BAR SCALE

0 30 60 90

SCALE: 1"=30'

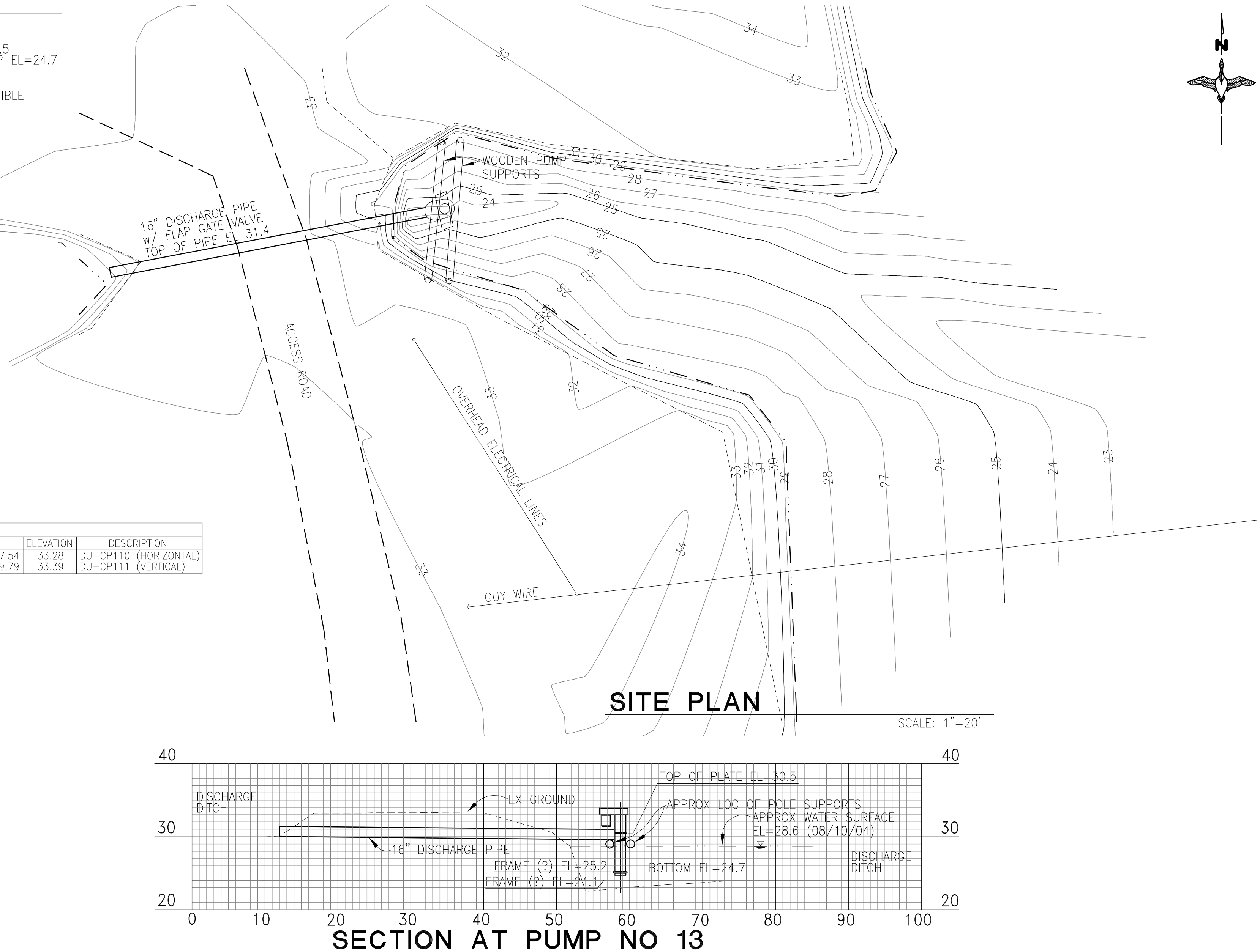
DUCKS UNLIMITED INC.
WESTERN REGIONAL OFFICE

JOB NUMBER CA-0181-001	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 12	DATE 10.15.04	
SURVEYED BY C WHITEHEAD		SHEET NO 1 -OF- 1	
DRAFTED BY: LKW			
APPROVED BY: CB			

PUMP DATA

PUMP BASE PLATE EL=30.5
APPROX BOTTOM OF PUMP EL=24.7

PUMP:
--- NO INFORMATION VISIBLE ---
(NO TAG)



SITE PLAN

SCALE: 1"=20'

SECTION AT PUMP NO 13

SCALE: 1"=20' HOR AND VER

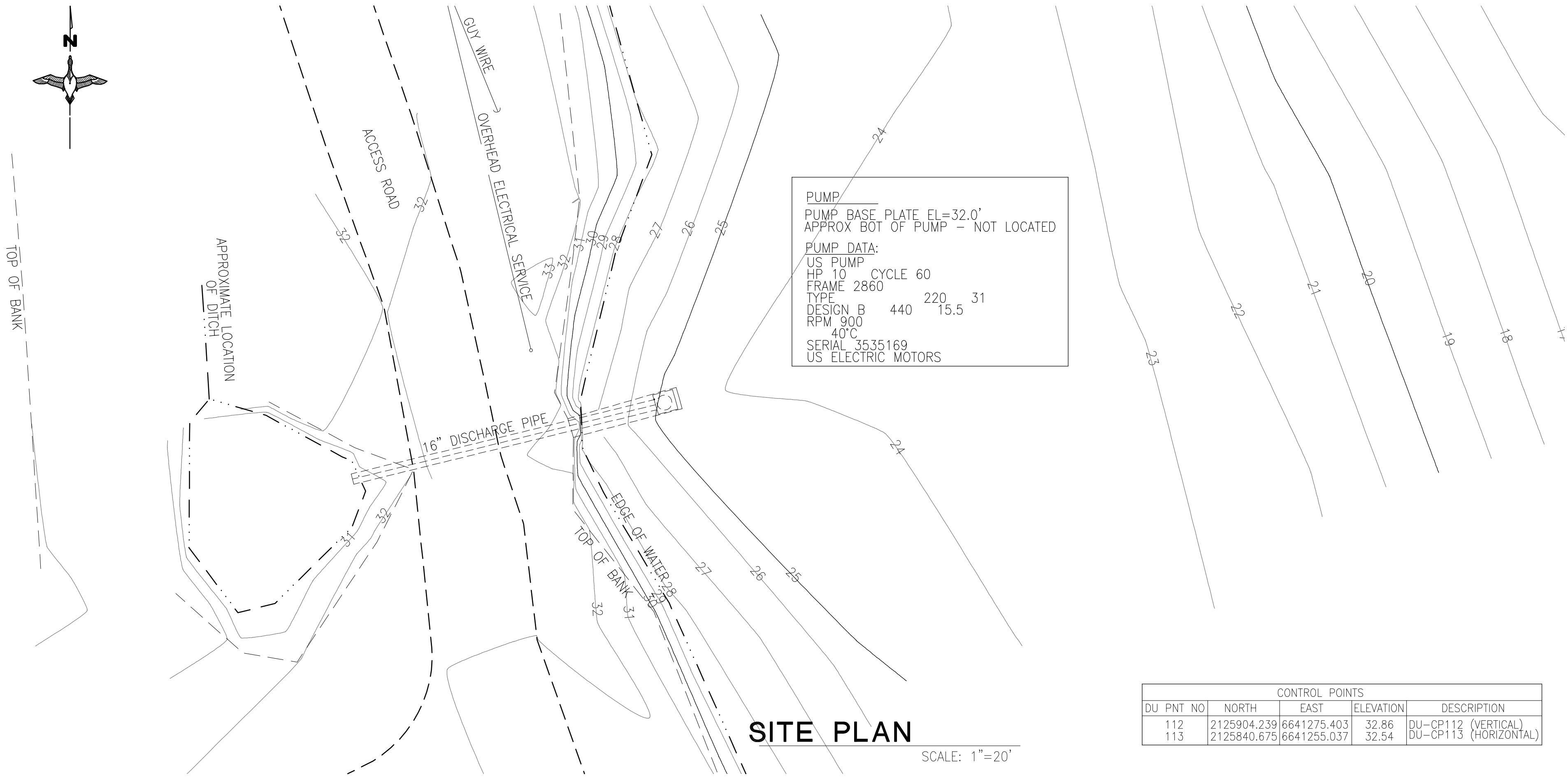
CONTROL POINTS				
DU PT NO	NORTH	EAST	ELEVATION	DESCRIPTION
110	2131948.64	6639727.54	33.28	DU-CP110 (HORIZONTAL)
111	2131985.31	6639719.79	33.39	DU-CP111 (VERTICAL)

BAR SCALE

0 20 40 60

SCALE: 1"=20'

DUCKS UNLIMITED INC. WESTERN REGIONAL OFFICE	JOB NUMBER CA-0181-001 SURVEYED BY C WHITEHEAD DRAFTED BY: LKW APPROVED BY: CB	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 13	DATE 10.15.04 SHEET NO 1 -OF- 1



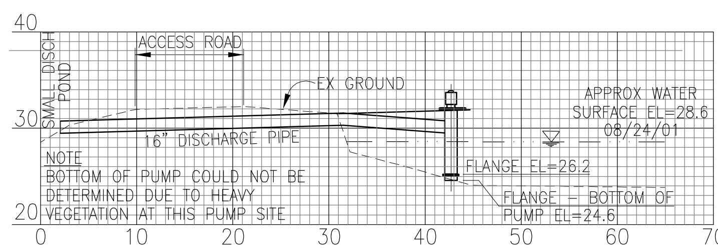
PUMP
PUMP BASE PLATE EL=32.0'
APPROX BOT OF PUMP – NOT LOCATED

PUMP DATA:
US PUMP
HP 10 CYCLE 60
FRAME 2860
TYPE 220 31
DESIGN B 440 15.5
RPM 900
40°C
SERIAL 3535169
US ELECTRIC MOTORS

SITE PLAN

SCALE: 1"=20'

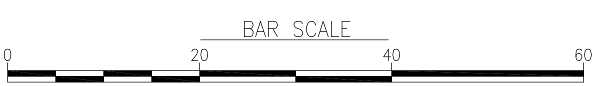
CONTROL POINTS				
DU PNT NO	NORTH	EAST	ELEVATION	DESCRIPTION
112	2125904.239	6641275.403	32.86	DU-CP112 (VERTICAL)
113	2125840.675	6641255.037	32.54	DU-CP113 (HORIZONTAL)



NOTE
BOTTOM OF PUMP COULD NOT BE DETERMINED DUE TO HEAVY VEGETATION AT THIS PUMP SITE

SECTION AT PUMP NO 14

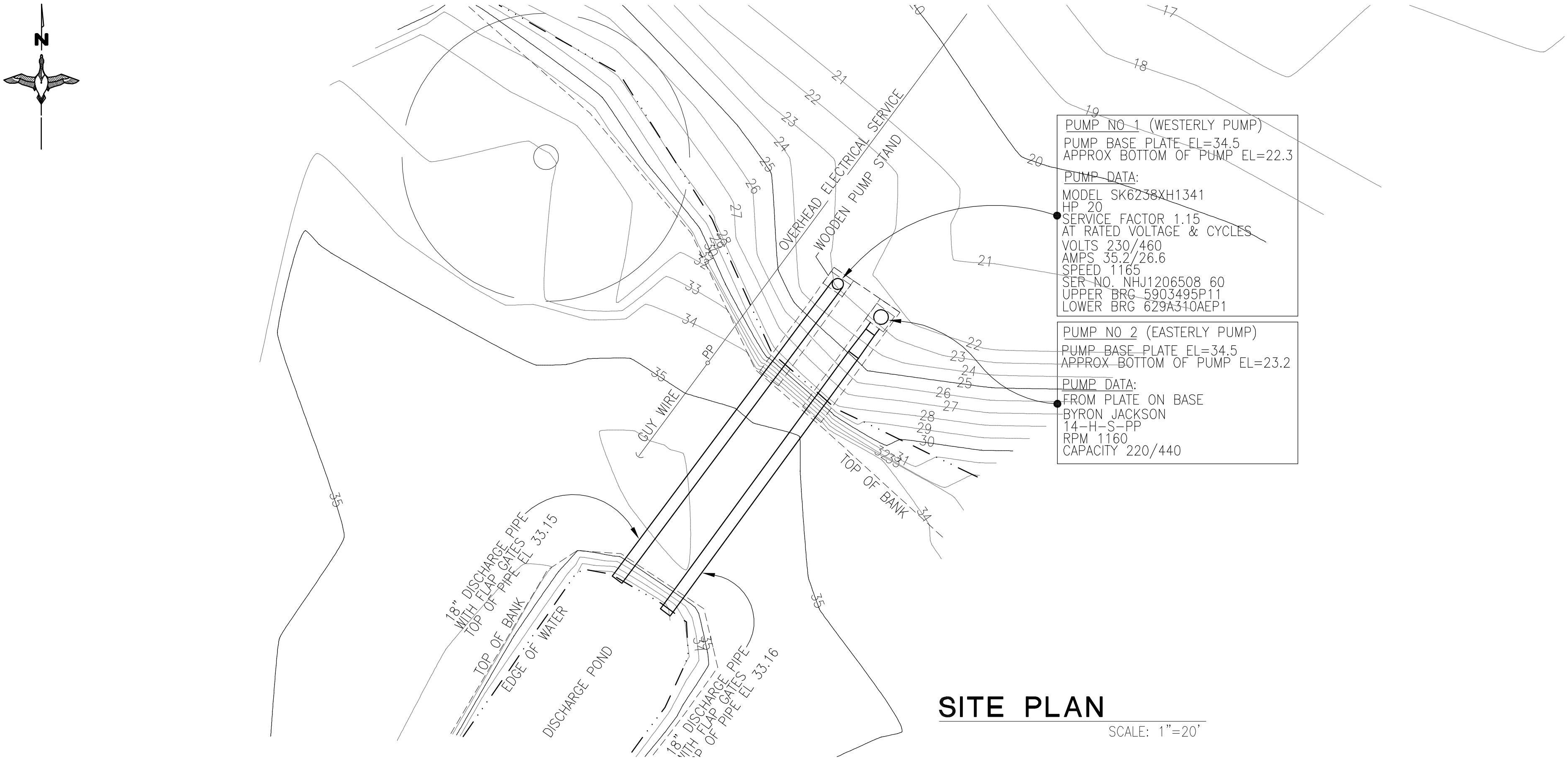
SCALE: 1"=20' HOR AND VER



SCALE: 1"=20'

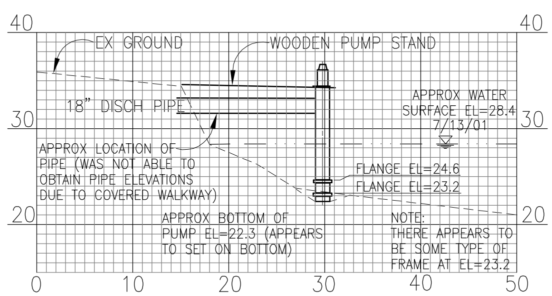
DUCKS UNLIMITED INC.
WESTERN REGIONAL OFFICE

JOB NUMBER CA-0181-001	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 14	DATE 10.15.04
SURVEYED BY C WHITEHEAD		SHEET NO 1 -OF- 1
DRAFTED BY: LKW		
APPROVED BY: CB		



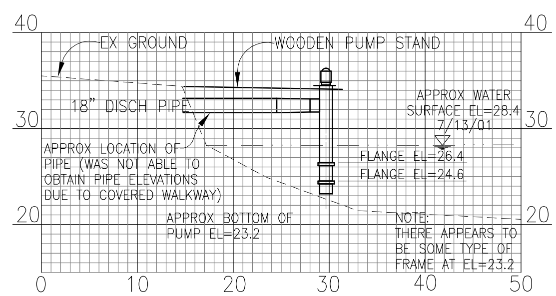
SITE PLAN

SCALE: 1"=20'



WESTERLY PUMP SECTION AT PUMP NO 15A

SCALE: 1"=20' HOR AND VER



EASTERLY PUMP SECTION AT PUMP NO 15A

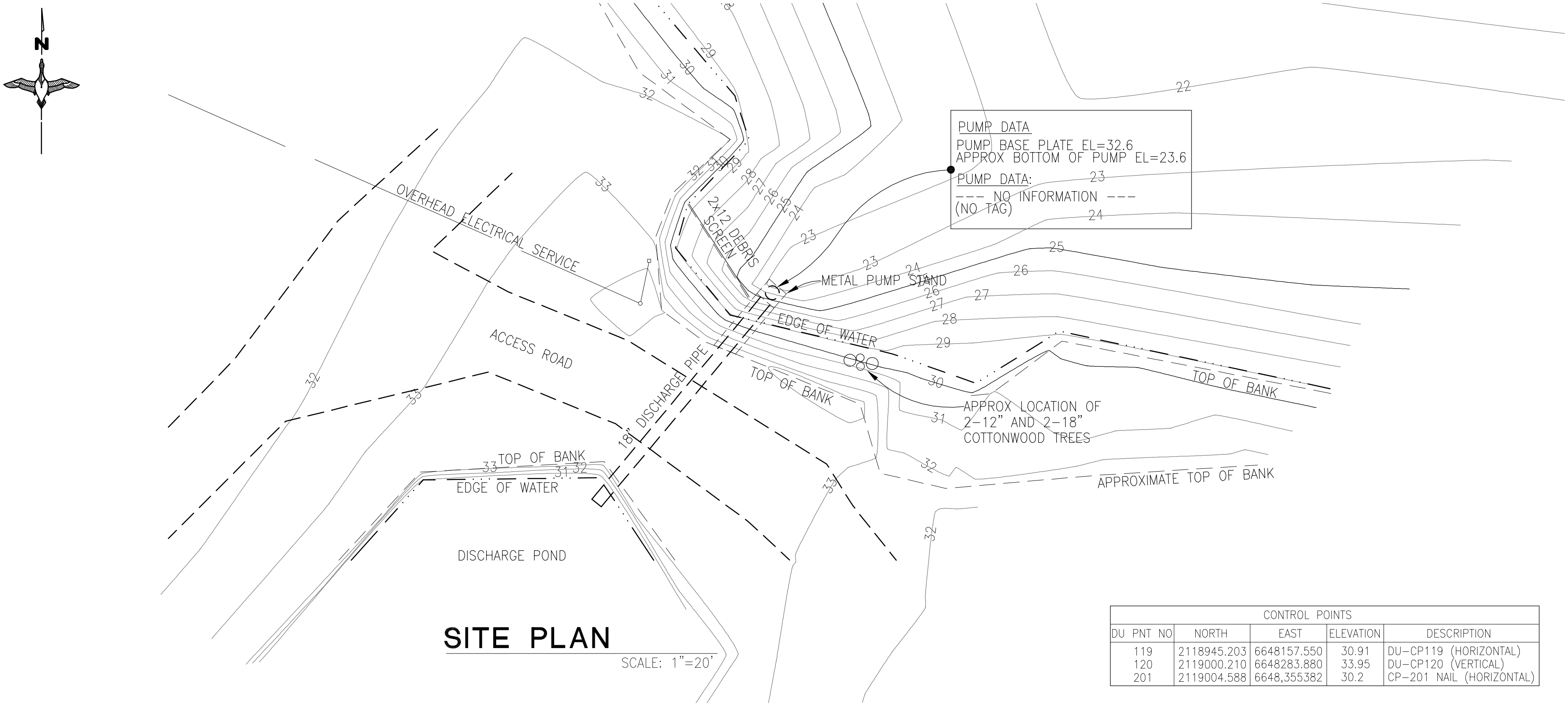
SCALE: 1"=20' HOR AND VER

BAR SCALE

0 20 40 60

SCALE: 1"=20'

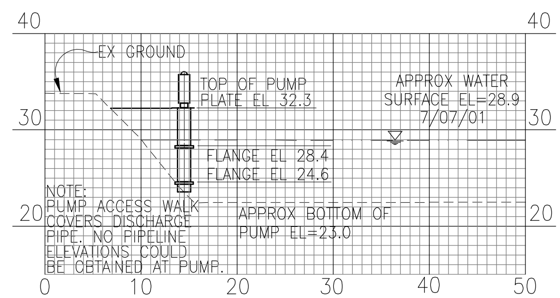
DUCKS UNLIMITED INC. WESTERN REGIONAL OFFICE	JOB NUMBER CA-0181-001 SURVEYED BY C WHITEHEAD DRAFTED BY: LKW APPROVED BY: CB	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 15A	DATE 10.15.04 SHEET NO 1 -OF- 1



SITE PLAN

SCALE: 1"=20'

CONTROL POINTS				
DU PNT NO	NORTH	EAST	ELEVATION	DESCRIPTION
119	2118945.203	6648157.550	30.91	DU-CP119 (HORIZONTAL)
120	2119000.210	6648283.880	33.95	DU-CP120 (VERTICAL)
201	2119004.588	6648,355382	30.2	CP-201 NAIL (HORIZONTAL)



SECTION AT PUMP NO 15B

SCALE: 1"=20' HOR AND VER

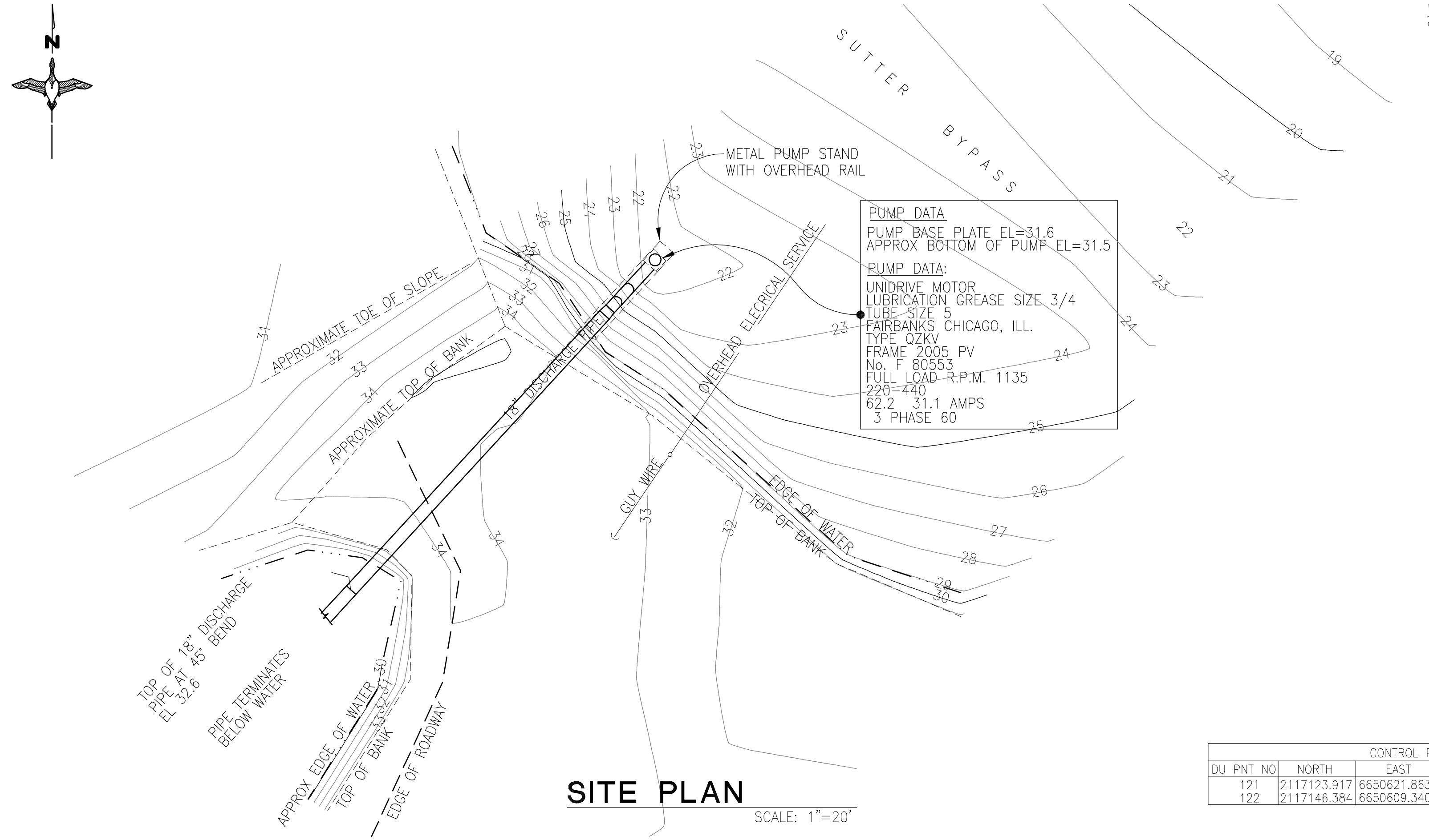
BAR SCALE

0 20 40 60

SCALE: 1"=20'

DUCKS UNLIMITED INC.
WESTERN REGIONAL OFFICE

JOB NUMBER CA-0181-001	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 15B	DATE 10.15.04
SURVEYED BY C WHITEHEAD		SHEET NO 1 -OF- 1
DRAFTED BY: LKW		
APPROVED BY: CB		



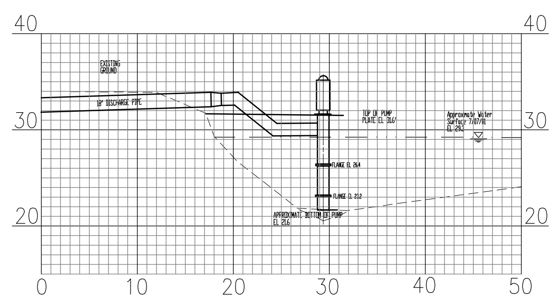
PUMP DATA
PUMP BASE PLATE EL=31.6
APPROX BOTTOM OF PUMP EL=31.5

PUMP DATA:
UNIDRIVE MOTOR
LUBRICATION GREASE SIZE 3/4
TUBE SIZE 5
FAIRBANKS CHICAGO, ILL.
TYPE QZKV
FRAME 2005 PV
No. F 80553
FULL LOAD R.P.M. 1135
220-440
62.2 31.1 AMPS
3 PHASE 60

SITE PLAN

SCALE: 1"=20'

CONTROL POINTS				
DU PNT NO	NORTH	EAST	ELEVATION	DESCRIPTION
121	2117123.917	6650621.863	33.461	DU-CP121 (VERTICAL)
122	2117146.384	6650609.340	35.17	DU-CP122 (HORIZONTAL)

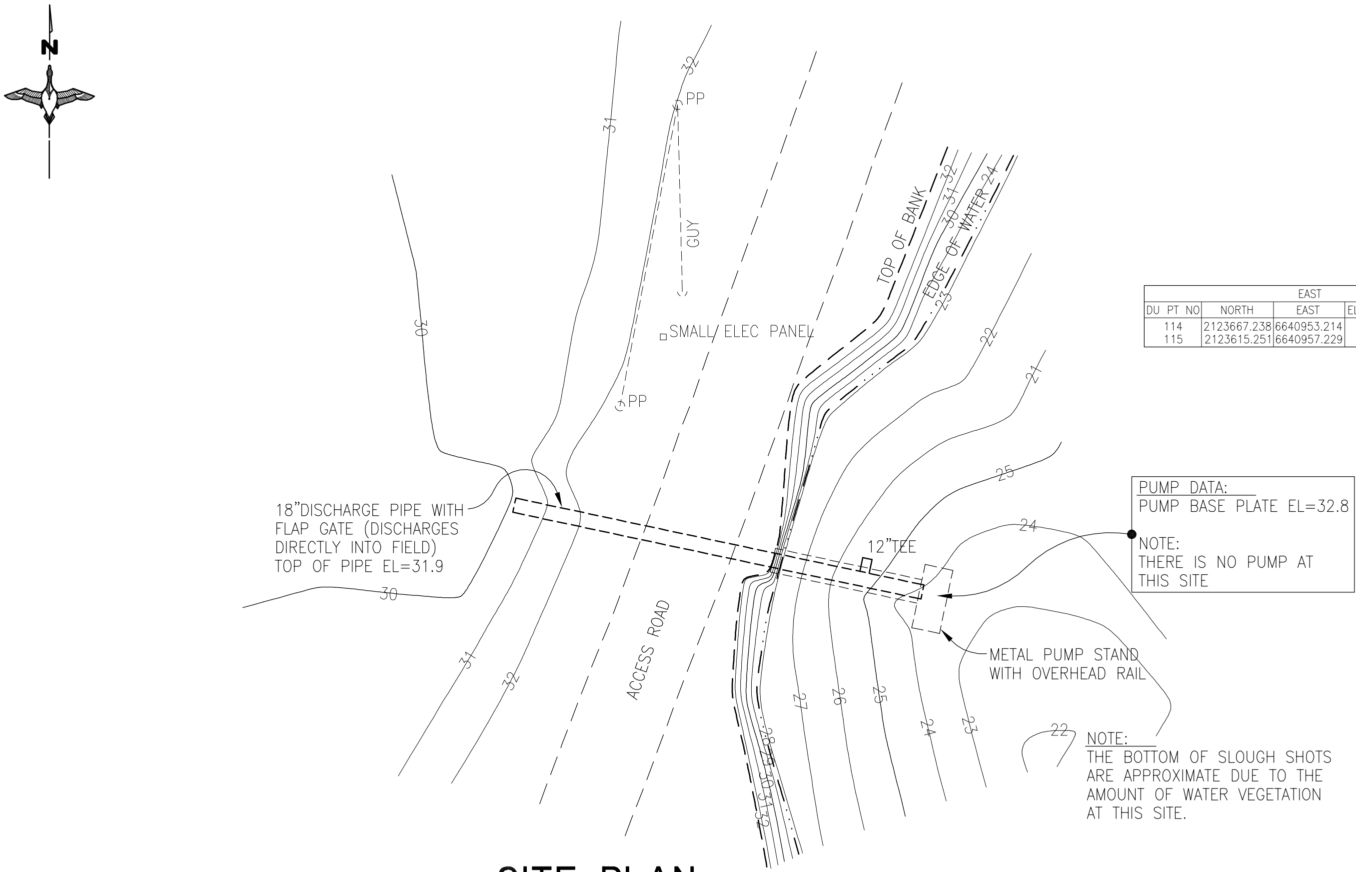


SECTION AT PUMP NO 15C

SCALE: 1"=20' HOR AND VER

BAR SCALE
0 20 40 60
SCALE: 1"=20'

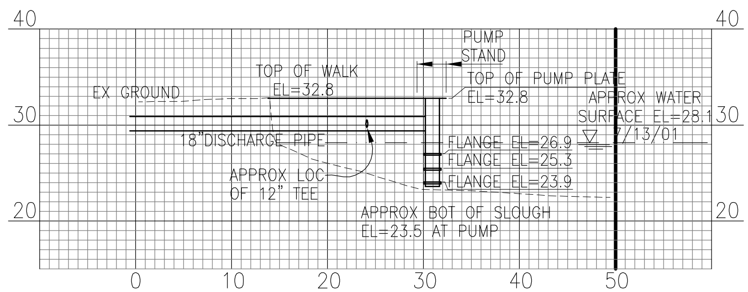
DUCKS UNLIMITED INC. WESTERN REGIONAL OFFICE	JOB NUMBER CA-0181-001 SURVEYED BY C WHITEHEAD DRAFTED BY: LKW APPROVED BY: CB	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 15C	DATE 10.15.04 SHEET NO 1 -OF- 1



		EAST		
DU PT NO	NORTH	EAST	ELEVATION	DESCRIPTION
114	2123667.238	6640953.214	32.88	DU-CP 114 (HORIZONTAL)
115	2123615.251	6640957.229	33.09	DU-CP 115 (VERTICAL)

SITE PLAN

SCALE: 1"=20'



SECTION AT PUMP NO 16

SCALE: 1"=20'HOR AND 1"=2' VER

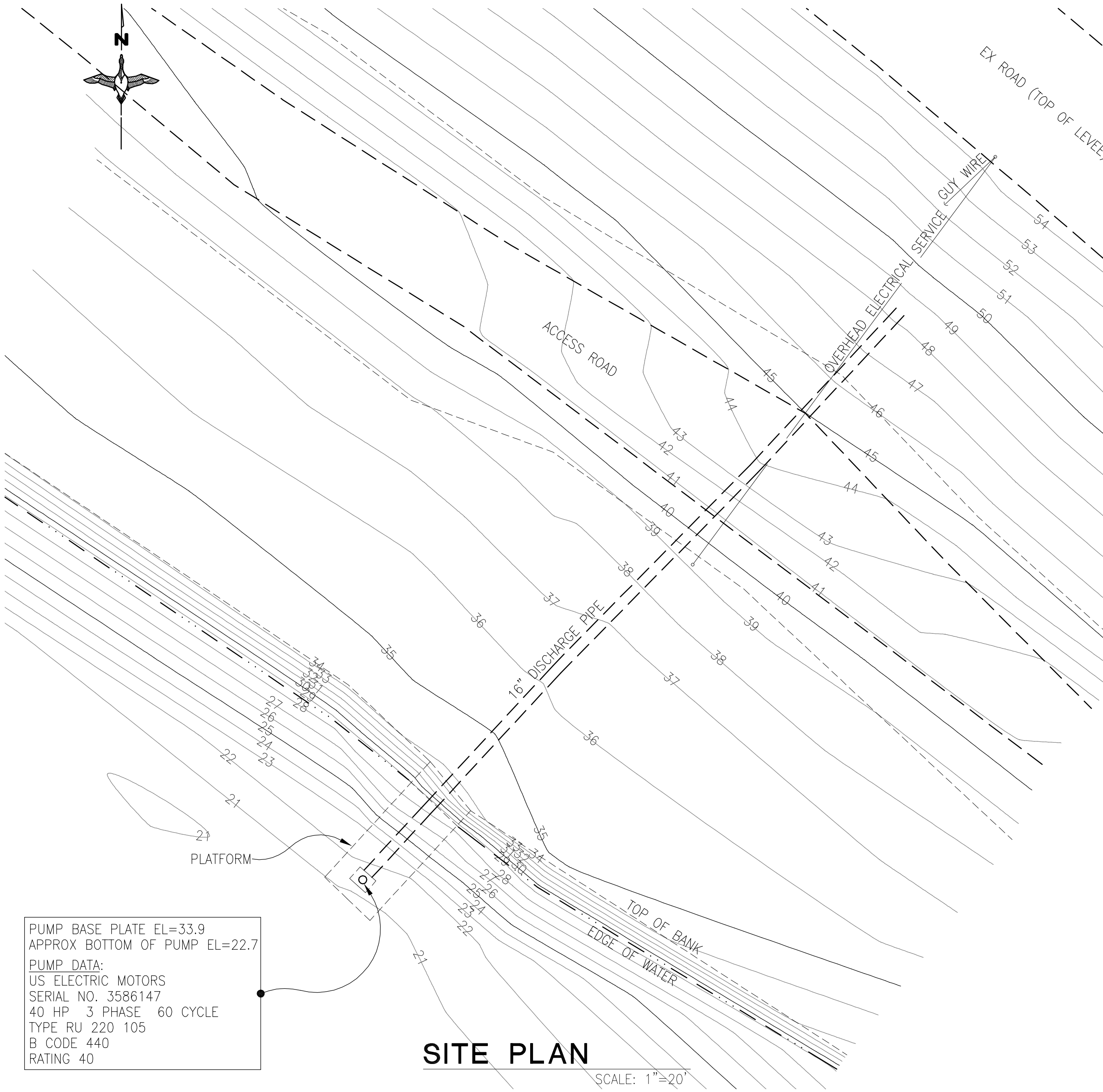
BAR SCALE

0 20 40 60

SCALE: 1"=20'

DUCKS UNLIMITED INC.
WESTERN REGIONAL OFFICE

JOB NUMBER CA-0181-001	SUTTER BYPASS EAST	DATE	10.15.04
SURVEYED BY C WHITEHEAD	BORROW CANAL PUMPS	SHEET NO	1 -OF- 1
DRAFTED BY: LKW	PUMP SITE 16		
APPROVED BY: CB			

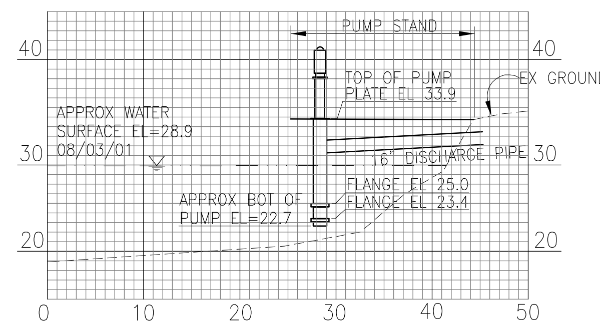


PUMP BASE PLATE EL=33.9
APPROX BOTTOM OF PUMP EL=22.7
PUMP DATA:
US ELECTRIC MOTORS
SERIAL NO. 3586147
40 HP 3 PHASE 60 CYCLE
TYPE RU 220 105
B CODE 440
RATING 40

SITE PLAN

SCALE: 1"=20'

CONTROL POINTS				
DU PNT NO	NORTH	EAST	ELEVATION	DESCRIPTION
125	2118630.952	6649235.663	52.2	DU-CP125 (HORIZONTAL)
126	2118604.438	6649198.750	42.8	DU-CP126 (VERTICAL)



SECTION AT PUMP NO 17

SCALE: 1"=20' HOR AND VER

BAR SCALE

0 20 40 60

SCALE: 1"=20'

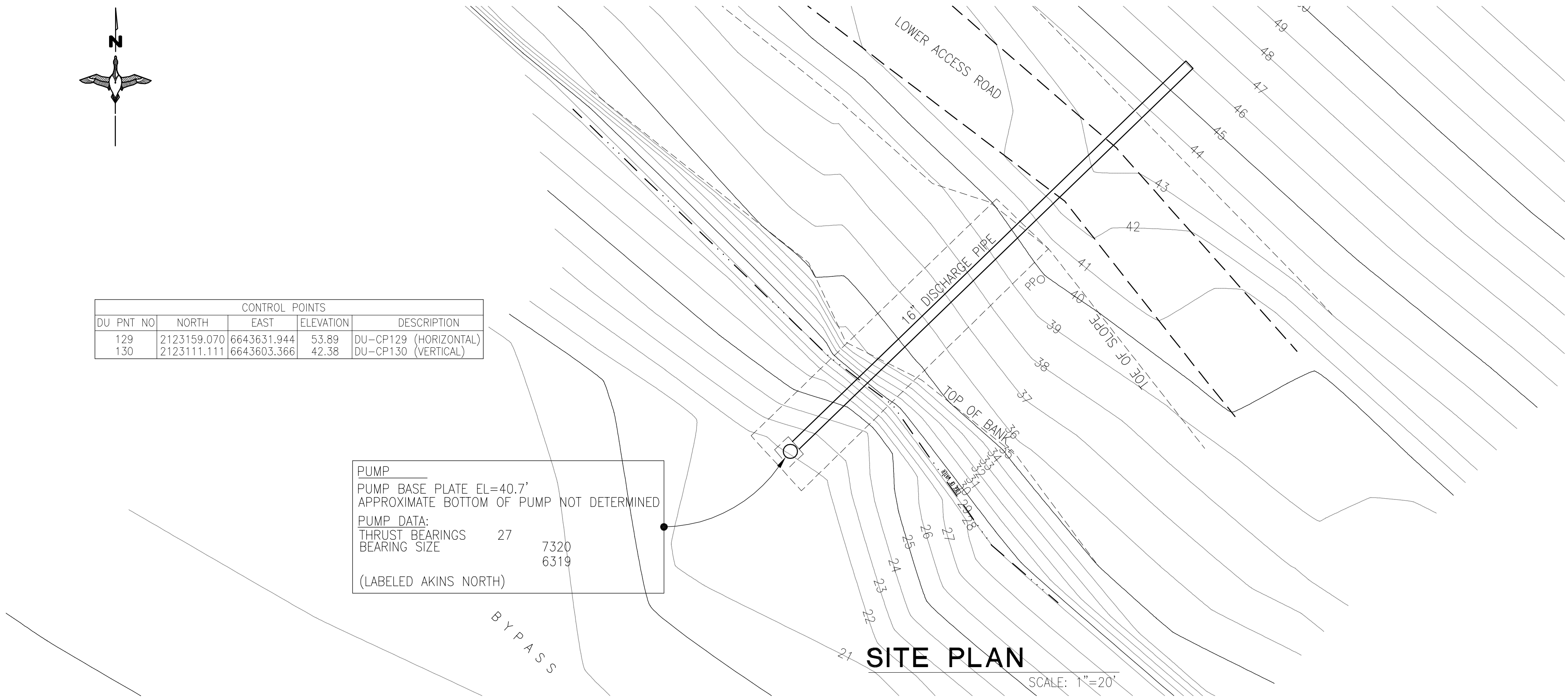
DUCKS UNLIMITED INC.
WESTERN REGIONAL OFFICE

JOB NUMBER CA-0181-001
SURVEYED BY C WHITEHEAD
DRAFTED BY: LKW
APPROVED BY: CB

SUTTER BYPASS EAST
BORROW CANAL PUMPS
PUMP SITE 17

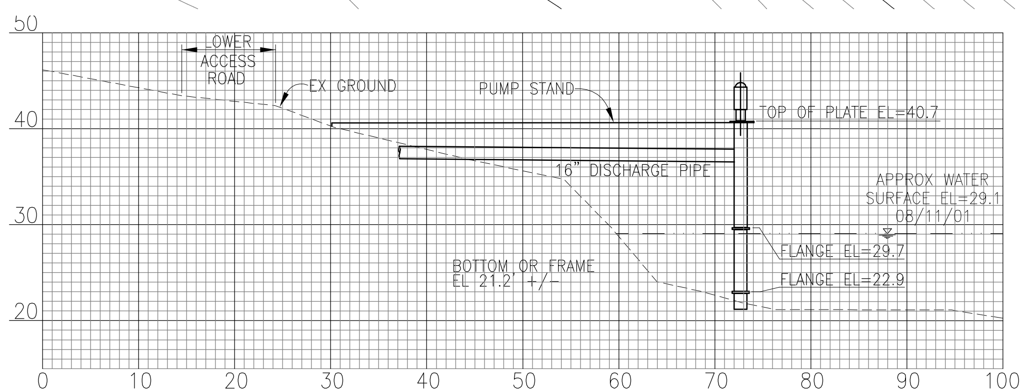
DATE 10.15.04
SHEET NO 1 -OF- 1

CONTROL POINTS				
DU PNT NO	NORTH	EAST	ELEVATION	DESCRIPTION
129	2123159.070	6643631.944	53.89	DU-CP129 (HORIZONTAL)
130	2123111.111	6643603.366	42.38	DU-CP130 (VERTICAL)



SITE PLAN

SCALE: 1"=20'



SECTION AT PUMP NO 17A

SCALE: 1"=20' HOR AND VER

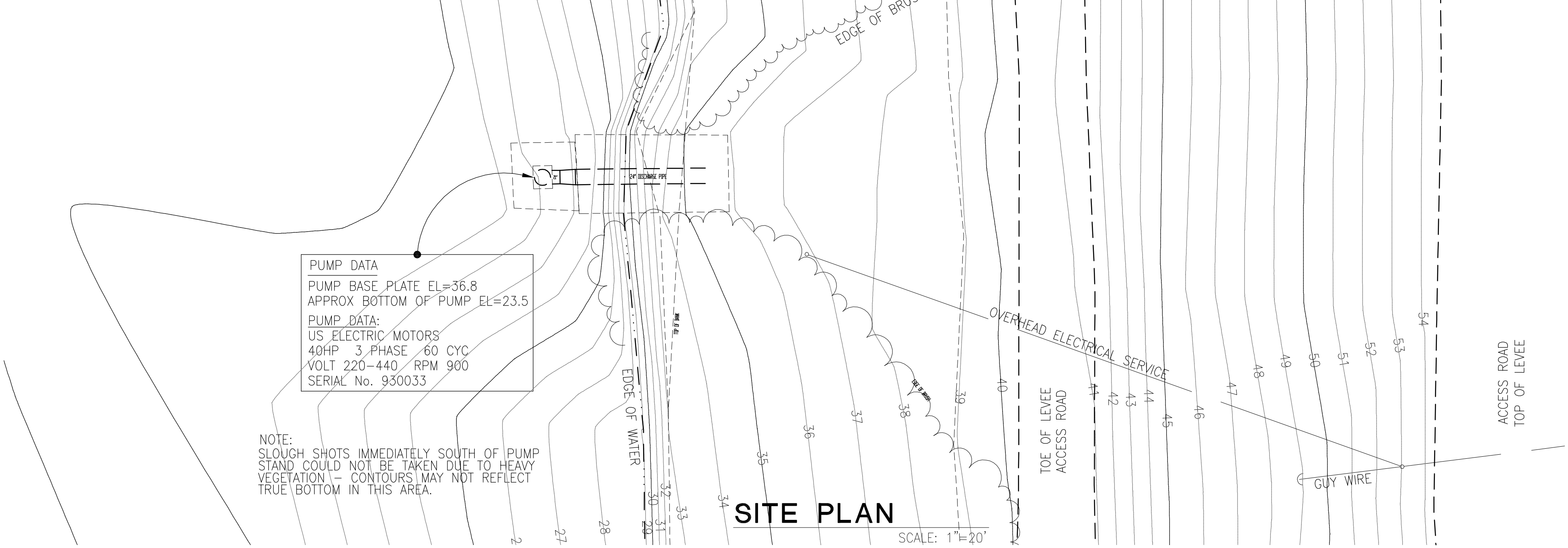
BAR SCALE

0 20 40 60

SCALE: 1"=20'

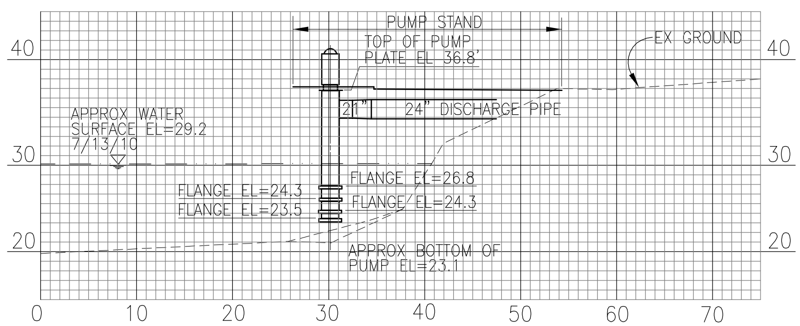
DUCKS UNLIMITED INC. WESTERN REGIONAL OFFICE	JOB NUMBER CA-0181-001 SURVEYED BY C WHITEHEAD DRAFTED BY: LKW APPROVED BY: CB	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 17A	DATE 10.15.04 SHEET NO 1 -OF- 1

CONTROL POINTS				
DU PNT NO	NORTH	EAST	ELEVATION	DESCRIPTION
127	2119285.499	6648395.489	48.70	DU-CP127 (HORIZONTAL)
128	2119282.153	6648337.546	40.34	DU-CP128 (VERTICAL)
201	2119243.679	6648391.906	40.1	CP-2x2 HUB
202	2119328.192	6648283.299	40.7	CP-NAIL
203	2119240.347	6648307.202	36.9	CP-NAIL



SITE PLAN

SCALE: 1"=20'



SECTION AT PUMP NO 17B

SCALE: 1"=20' HOR AND VER

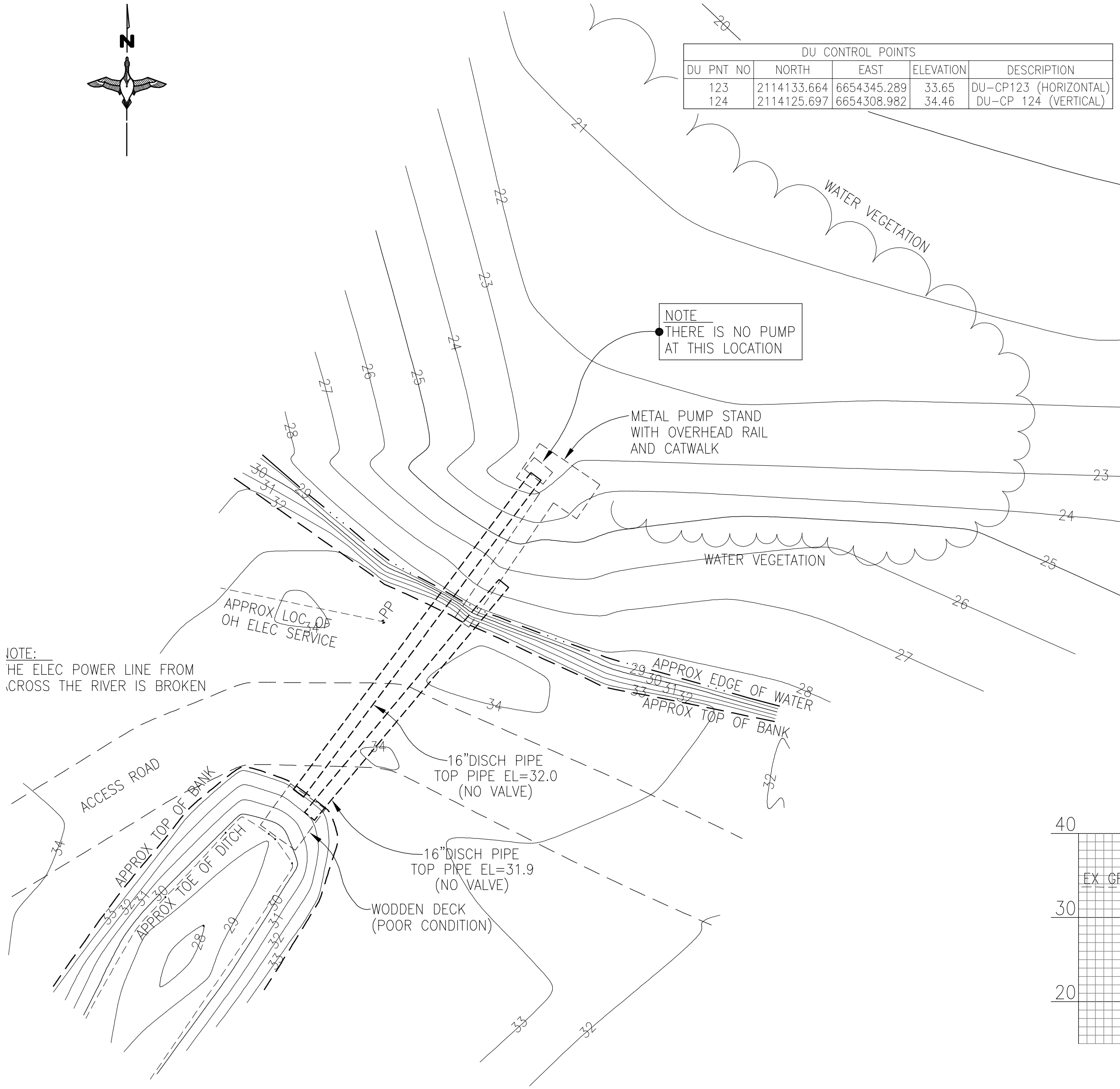
BAR SCALE

0 20 40 60

SCALE: 1"=20'

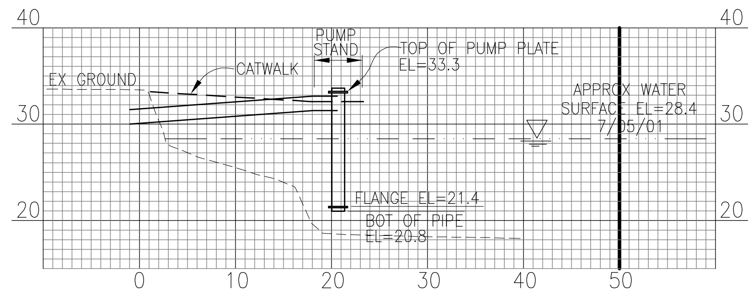
DUCKS UNLIMITED INC. WESTERN REGIONAL OFFICE	JOB NUMBER CA-0181-001	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 17B	DATE 10.15.04
	SURVEYED BY C WHITEHEAD		SHEET NO 1 -OF- 1
	DRAFTED BY: LKW		
	APPROVED BY: CB		

DU CONTROL POINTS				
DU PNT NO	NORTH	EAST	ELEVATION	DESCRIPTION
123	2114133.664	6654345.289	33.65	DU-CP123 (HORIZONTAL)
124	2114125.697	6654308.982	34.46	DU-CP 124 (VERTICAL)



SITE PLAN

SCALE: 1"=20'

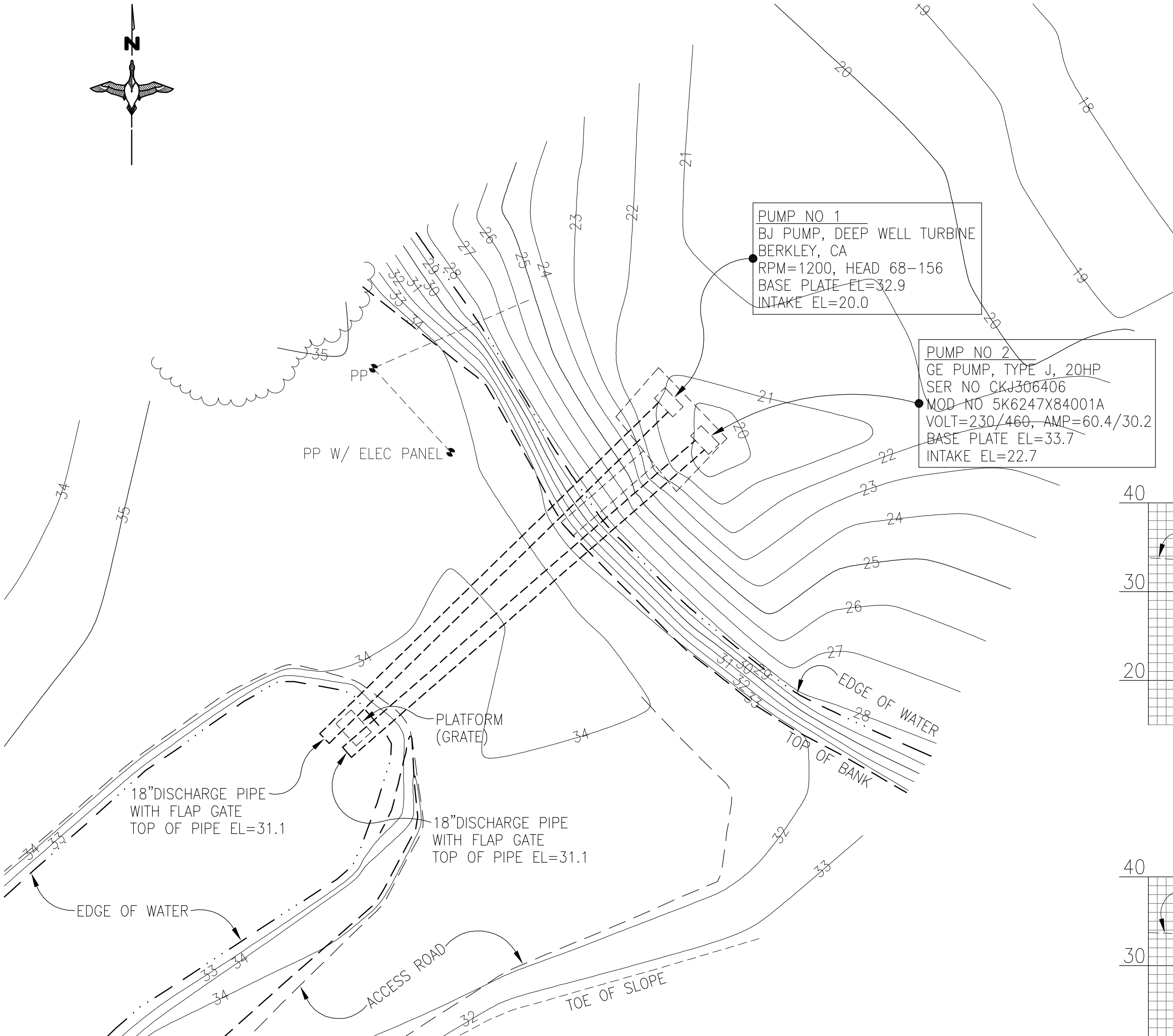


SECTION AT PUMP NO 18

SCALE: 1"=20'HOR AND 1"=2' VER

BAR SCALE
0 20 40 60
SCALE: 1"=20'

DUCKS UNLIMITED INC. WESTERN REGIONAL OFFICE	JOB NUMBER CA-0181-001 SURVEYED BY C WHITEHEAD DRAFTED BY: LKW APPROVED BY: CB	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 18	DATE 10.15.04 SHEET NO 1 -OF- 1



CONTROL POINTS				
DU PNT NO	NORTH	EAST	ELEVATION	DESCRIPTION
131	2111497.142	6656708.385	34.58	DU CP-131 (HORIZONTAL)
132	2111496.688	6656742.887	34.26	DU CP-132 (VERTICAL)

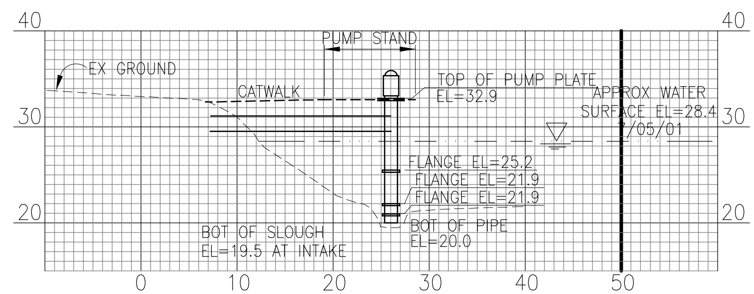
SITE PLAN

SCALE: 1"=20'

BAR SCALE

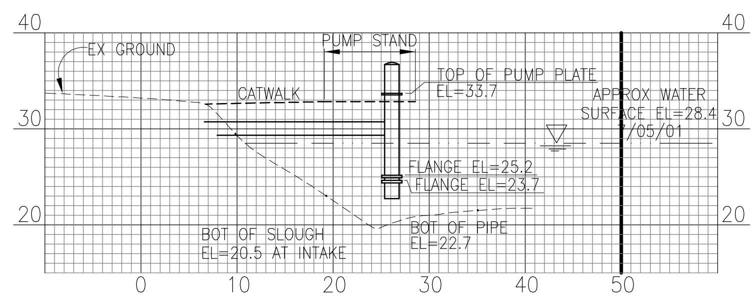
0 20 40 60

SCALE: 1"=20'



WESTERLY PUMP SECTION AT PUMP 19

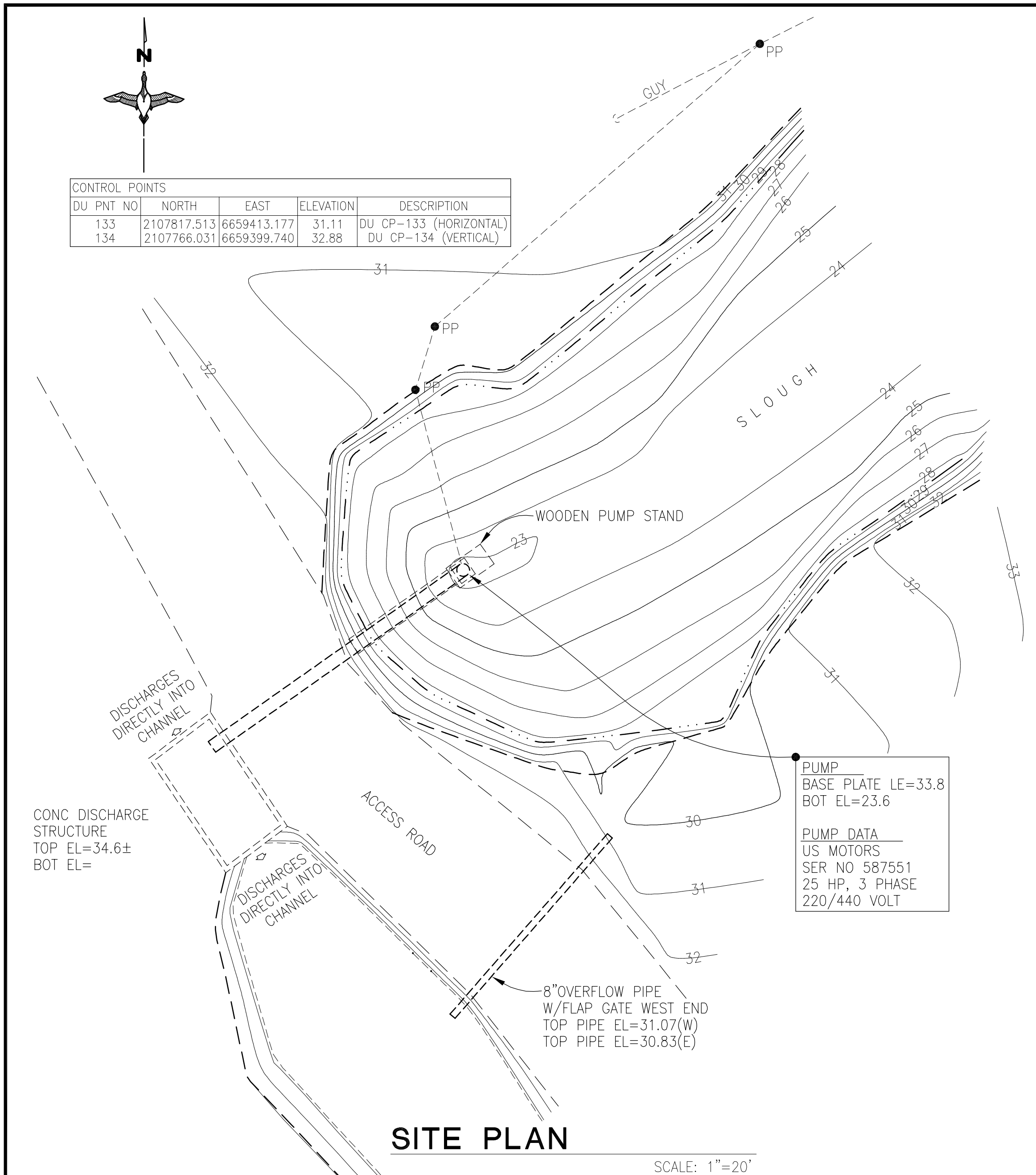
SCALE: 1"=20' HOR AND VER



EASTERLY PUMP SECTION AT PUMP 19

SCALE: 1"=20' HOR AND VER

DUCKS UNLIMITED INC. WESTERN REGIONAL OFFICE	JOB NUMBER CA-0181-001	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 19	DATE 10.15.04
	SURVEYED BY C WHITEHEAD		SHEET NO 1 -OF- 1
	DRAFTED BY: LKW		
	APPROVED BY: CB		

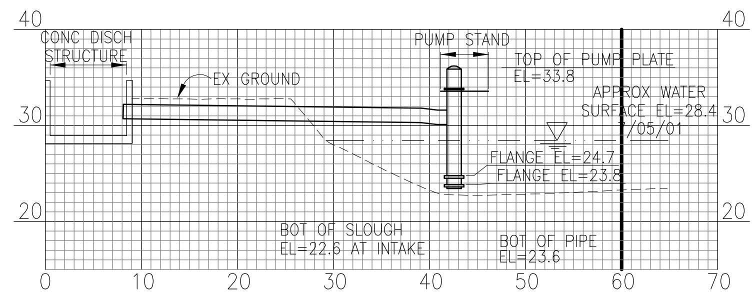


CONTROL POINTS

DU PNT NO	NORTH	EAST	ELEVATION	DESCRIPTION
133	2107817.513	6659413.177	31.11	DU CP-133 (HORIZONTAL)
134	2107766.031	6659399.740	32.88	DU CP-134 (VERTICAL)

SITE PLAN

SCALE: 1"=20'



SECTION AT PUMP 20

SCALE: 1"=20' HOR AND VER

BAR SCALE

0 20 40 60

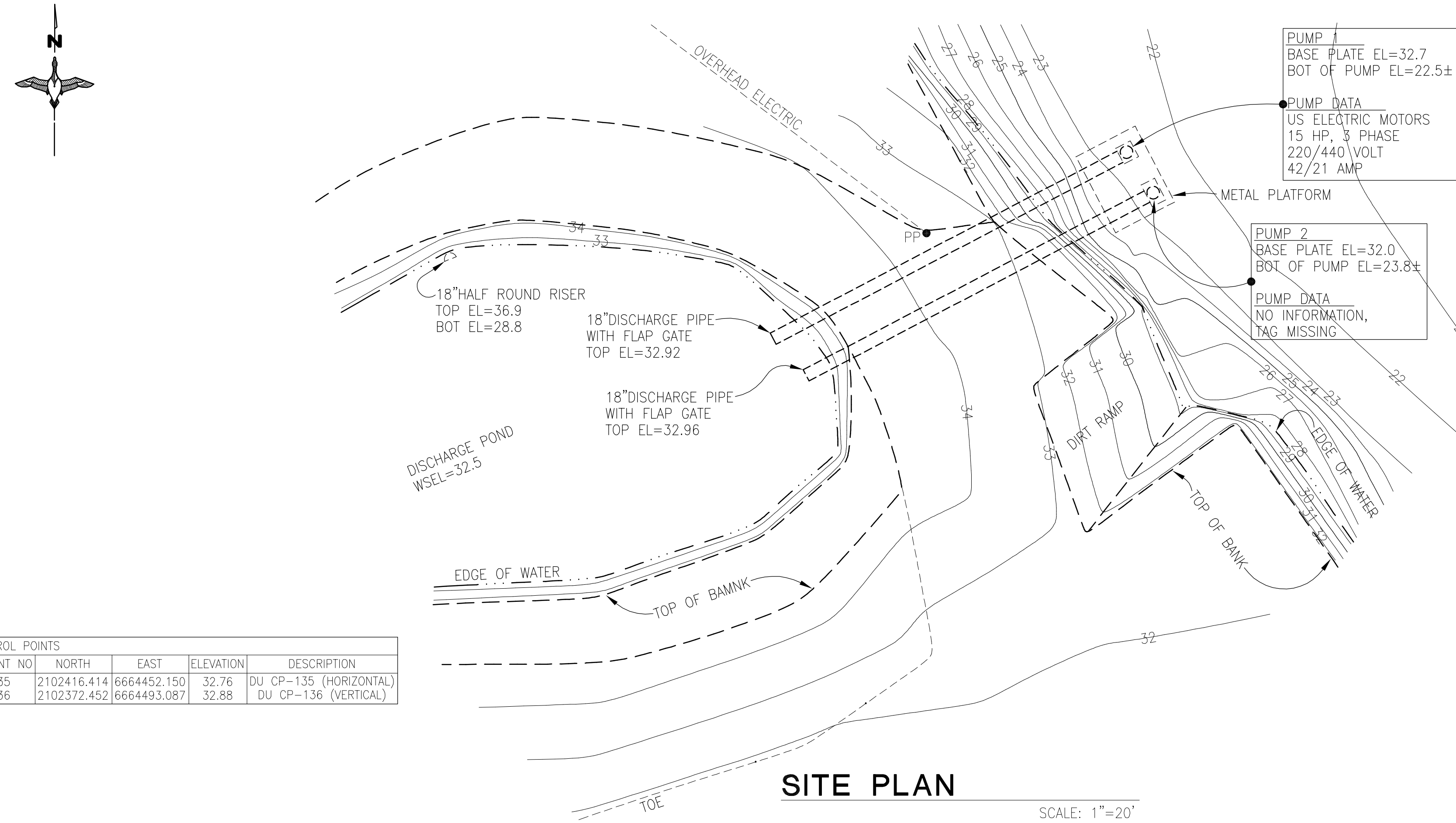
SCALE: 1"=20'

DUCKS UNLIMITED INC.
WESTERN REGIONAL OFFICE

JOB NUMBER CA-0181-001
SURVEYED BY C WHITEHEAD
DRAFTED BY: LKW
APPROVED BY: CB

SUTTER BYPASS EAST
BORROW CANAL PUMPS
PUMP SITE 20

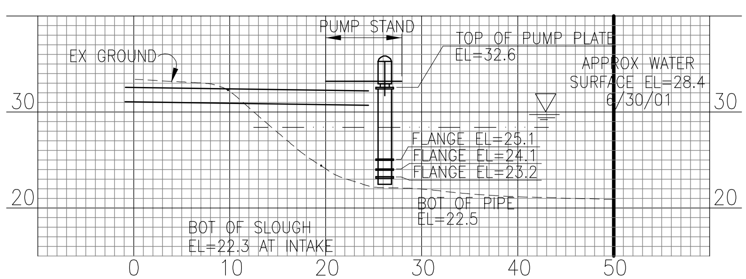
DATE 10.15.04
SHEET NO 1 -OF- 1



CONTROL POINTS				
DU PNT NO	NORTH	EAST	ELEVATION	DESCRIPTION
135	2102416.414	6664452.150	32.76	DU CP-135 (HORIZONTAL)
136	2102372.452	6664493.087	32.88	DU CP-136 (VERTICAL)

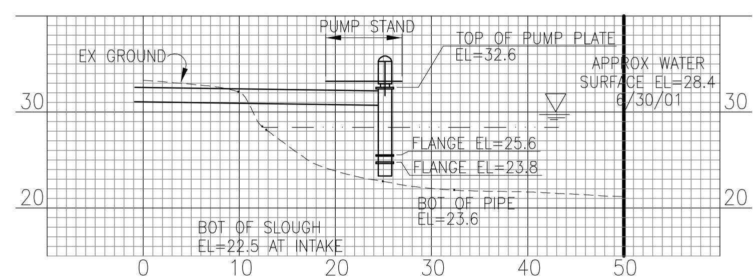
SITE PLAN

SCALE: 1"=20'



NORTHERLY PUMP SECTION AT PUMP 21

SCALE: 1"=20' HOR AND VER



SOUTHERLY PUMP SECTION AT PUMP 21

SCALE: 1"=20' HOR AND VER

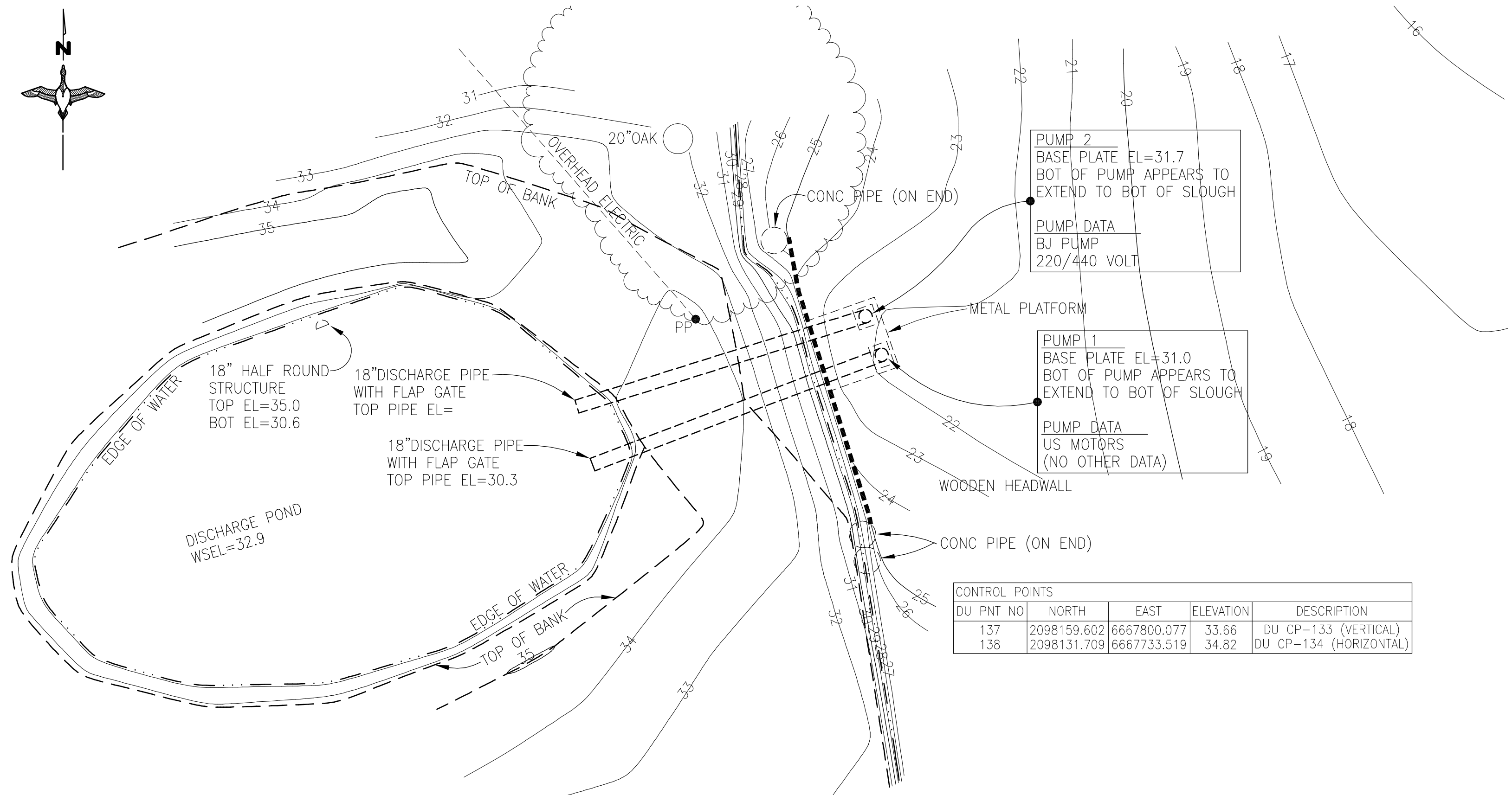
BAR SCALE

0 20 40 60

SCALE: 1"=20'

DUCKS UNLIMITED INC.
WESTERN REGIONAL OFFICE

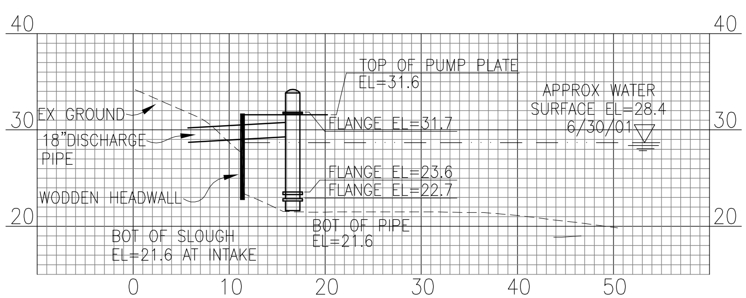
JOB NUMBER CA-0181-001	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 21	DATE 10.15.04	
SURVEYED BY C WHITEHEAD		SHEET NO 1 -OF- 1	
DRAFTED BY: LKW			
APPROVED BY: CB			



CONTROL POINTS				
DU PNT NO	NORTH	EAST	ELEVATION	DESCRIPTION
137	2098159.602	6667800.077	33.66	DU CP-133 (VERTICAL)
138	2098131.709	6667733.519	34.82	DU CP-134 (HORIZONTAL)

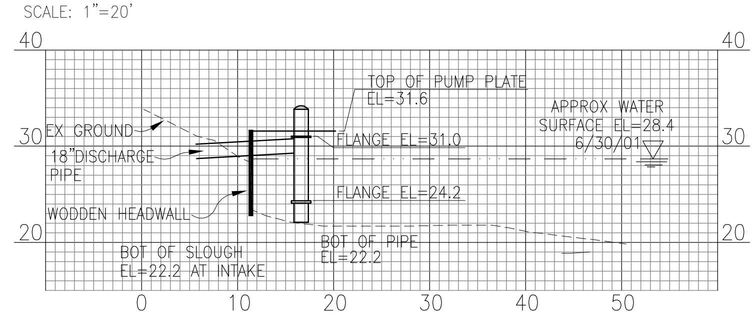
SITE PLAN

SCALE: 1"=20'



SOUTHERLY PUMP SECTION AT PUMP 22

SCALE: 1"=20' HOR AND VER



NORTHERLY PUMP SECTION AT PUMP 22

SCALE: 1"=20' HOR AND VER

BAR SCALE

0 20 40 60

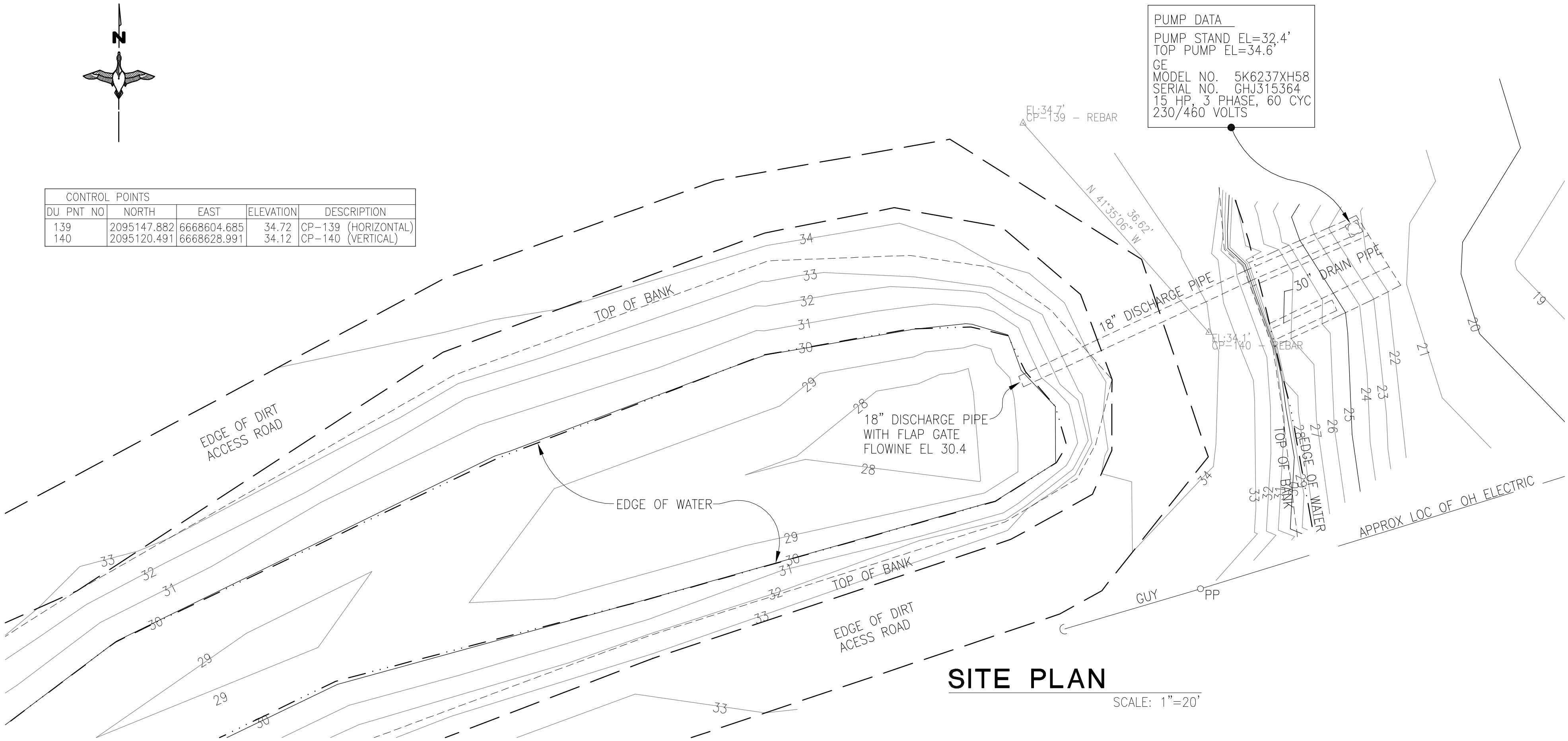
SCALE: 1"=20'

DUCKS UNLIMITED INC.
WESTERN REGIONAL OFFICE

JOB NUMBER CA-0181-001
SURVEYED BY C WHITEHEAD
DRAFTED BY: LKW
APPROVED BY: CB

SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 22

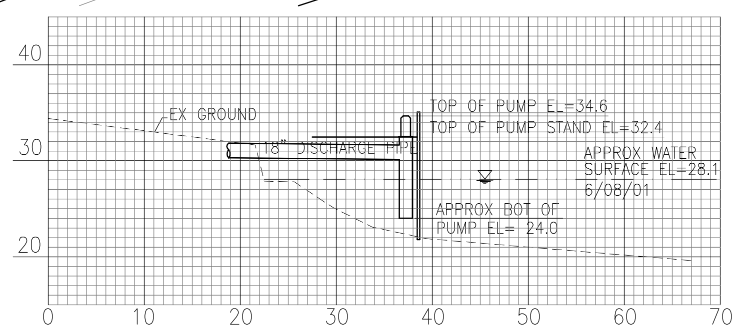
DATE 10.15.04
SHEET NO 1 -OF- 1



CONTROL POINTS				
DU PNT NO	NORTH	EAST	ELEVATION	DESCRIPTION
139	2095147.882	6668604.685	34.72	CP-139 (HORIZONTAL)
140	2095120.491	6668628.991	34.12	CP-140 (VERTICAL)

SITE PLAN

SCALE: 1"=20'



SECTION AT PUMP NO 23

SCALE: 1"=20' HOR AND VER

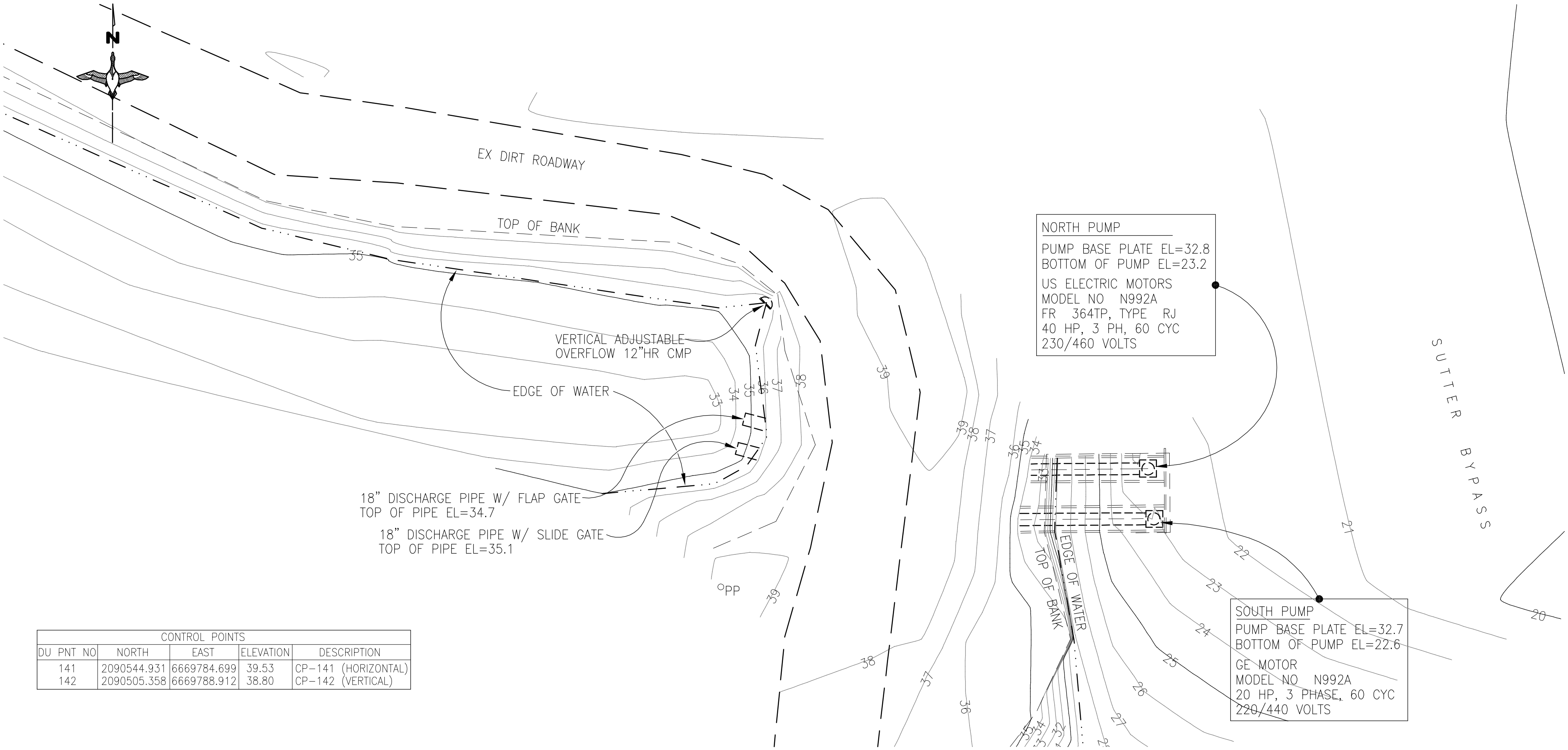
BAR SCALE

0 20 40 60

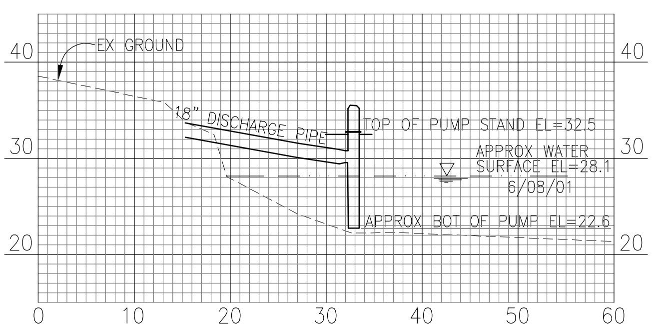
SCALE: 1"=20'

DUCKS UNLIMITED INC.
WESTERN REGIONAL OFFICE

JOB NUMBER CA-0181-001	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 23	DATE 10.15.04	
SURVEYED BY C WHITEHEAD		SHEET NO 1 -OF- 1	
DRAFTED BY: LKW			
APPROVED BY: CB			



CONTROL POINTS				
DU PNT NO	NORTH	EAST	ELEVATION	DESCRIPTION
141	2090544.931	6669784.699	39.53	CP-141 (HORIZONTAL)
142	2090505.358	6669788.912	38.80	CP-142 (VERTICAL)



SECTION AT PUMP NO 24
(AT SOUTH PUMP)

SCALE: 1"=20' HOR AND VER

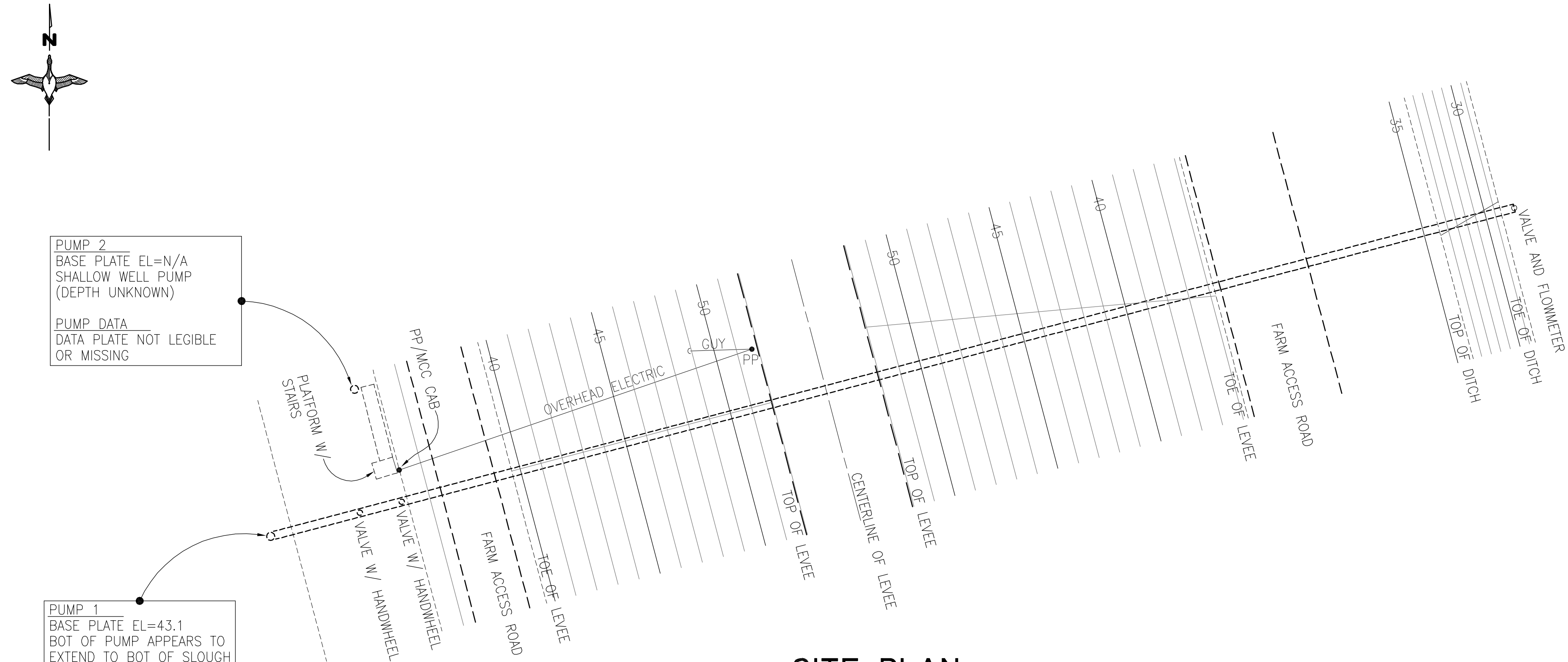
BAR SCALE

0 20 40 60

SCALE: 1"=20'

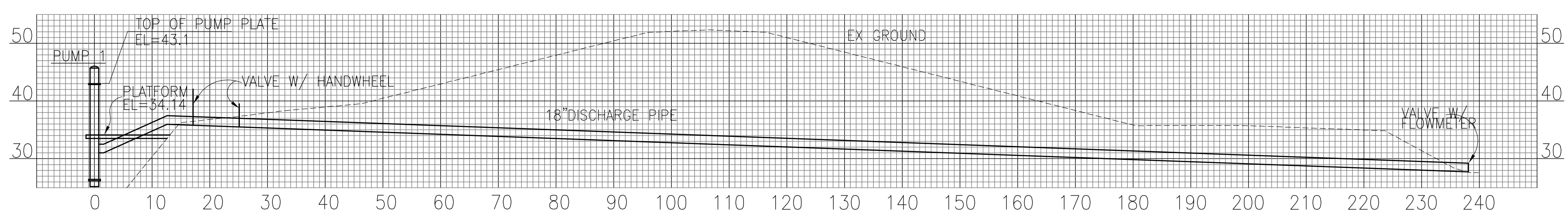
DUCKS UNLIMITED INC.
WESTERN REGIONAL OFFICE

JOB NUMBER CA-0181-001	SUTTER BYPASS EAST	DATE 10.15.04	
SURVEYED BY C WHITEHEAD	BORROW CANAL PUMPS	SHEET NO 1 -OF- 1	
DRAFTED BY: LKW	PUMP SITE 24		
APPROVED BY: CB			



SITE PLAN

SCALE: 1"=30'



SECTION AT PUMP 25

SCALE: 1"=30' HOR AND VER

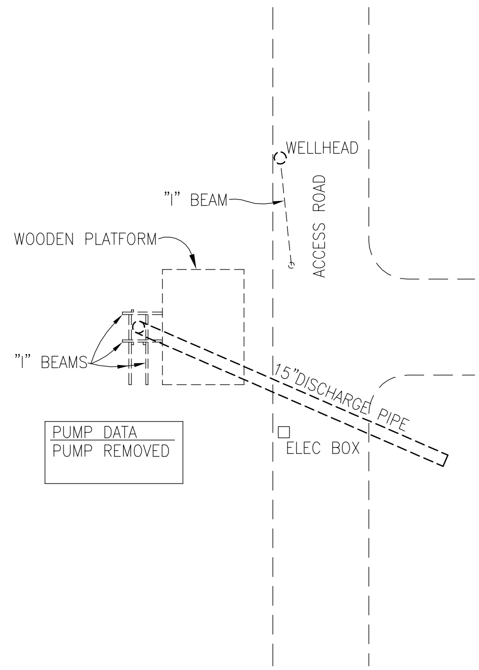
BAR SCALE

0 30 60 90

SCALE: 1"=30'

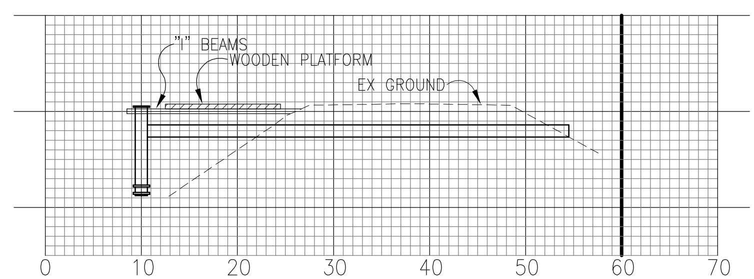
DUCKS UNLIMITED INC.
WESTERN REGIONAL OFFICE

JOB NUMBER CA-0181-001	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 25	DATE 10.15.04
SURVEYED BY C WHITEHEAD		SHEET NO 1 -OF- 1
DRAFTED BY: LKW		
APPROVED BY: CB		



SITE PLAN

SCALE: 1"=20'

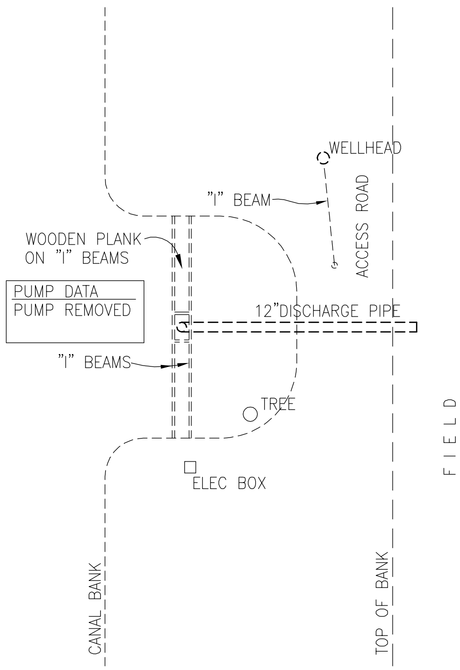


SECTION AT PUMP 1W

SCALE: 1"=20' HOR AND VER

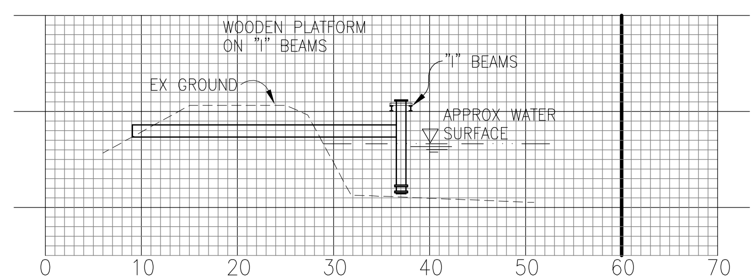
SCALE: 1"=20'

DUCKS UNLIMITED INC. WESTERN REGIONAL OFFICE	JOB NUMBER CA-0181-001 SURVEYED BY C WHITEHEAD DRAFTED BY: LKW APPROVED BY: CB	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 1W	DATE 10.15.04 SHEET NO 1 -OF- 1



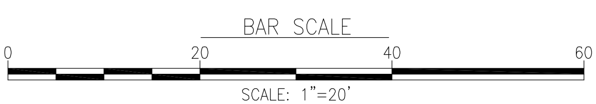
SITE PLAN

SCALE: 1"=20'



SECTION AT PUMP 2W

SCALE: 1"=20' HOR AND VER



DUCKS UNLIMITED INC. WESTERN REGIONAL OFFICE	JOB NUMBER CA-0181-001 SURVEYED BY C WHITEHEAD DRAFTED BY: LKW APPROVED BY: CB	SUTTER BYPASS EAST BORROW CANAL PUMPS PUMP SITE 2W	DATE 10.15.04 SHEET NO 1 -OF- 1